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## NOTES ON CEMENTS, MORTARS AND CONCRETES.

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### WITH DISCUSSION.

The rules formulated by the Committee of the Society on a uniform system for tests of cement, with notes as to the quality and treatment of the material, etc., have been of great value, as shown by their general adoption by engineers throughout the country. They were a step forward when much needed; and the author thinks it would not be too much to say that no greater service has been rendered to the profession by our Society than by the bringing out of that paper. While such commendable service has been rendered by the labors of the Committee, many other papers on the same general topic have been contributed by other members to the *Transactions* of the Society; these, with the discussions they have elicited, would seem to have so far exhausted the subject as to make it a venturesome business to approach it with new matter. There is still, however, room for expansion—room for additional information, and rules for guidance in practically dealing with this invaluable material in the many details of everyday practice. Much as we know about its remarkable properties, it must be admitted that there is yet a good deal that we do not know.

It has been said that "mortar is the soul of masonry," and masonry constitutes not only the soul but the body of most engineering constructions. The author does not set himself to the task of evolving anything especially new upon the subject. This remains for the few in the profession who have the time, means and other requisites for the object, and who may have the laudable desire to pursue the search to its fuller development. He merely aims in this paper to call attention to such needs and deficiencies as pertain rather to our present knowledge and practice, and to make a few suggestions in regard to them, at the same time trespassing as little as possible on previously well-trodden ground.

Reference is now made to notes taken while superintending the construction of the new Naval Observatory on Georgetown Heights, Washington, D. C. This work consisted of a group of nine buildings, a sketch of the positions of which, on a small scale, is appended hereto. They are designated as per sketch (Plate LVII):

No. 1 Main building, 69 x 307 feet; No. 2 Grand equatorial, 46 x 72 feet; No. 3 Clock-room, 18 x 20 feet; Nos. 4 and 5 Observers' rooms, 18 x 20 feet; Nos. 6 and 7 Transit circle buildings, 30 x 40 feet; No. 8 Prime vertical building, 18 x 20 feet; No. 9 Boiler-house, 45 x 54 feet. *A*, *B* and *C* are underground ducts for steam heating and water-pipes, connected with the boiler-house.

They are all fire-proof, except Nos. 4 and 5. These, in consequence of the stinted appropriation, had to be economized in superstructure, although the foundations and basements were constructed in conformity with the other buildings. It is expected that the cheaper work will be replaced later with marble and iron. Nos. 1, 2 and 3 are of marble, with foundations of gneiss, the backing and interior walls of brick. Nos. 6 and 7, foundations and basements of gneiss, with iron superstructures. A third building of the same kind forms a part of the main building at the west end. No. 8 is the same as Nos. 6 and 7. No. 9 has exterior walls of broken range gneiss, with interior walls of brick; it is situated on side-hill ground, and has a flat roof of iron beams and brick arches, with paved surface for driving on with coal carts. The foundations are deep and walls heavy. The work was done under contract with the Navy Department. The specifications were prepared by the architect, Mr. R. M. Hunt, and were full and stringent. It is to be observed that the contract was drawn so as to allow but little discretion or latitude in the interpretation of its spirit and letter.

The restrictions were rather in excess of those in contracts for work other than for the United States Government. Officers and agents were held to a strict accountability, and it required great care not to overlook stipulated conditions or to exceed them in any respect; such precautions having doubtless been induced by the necessity of avoiding the giving to contractors a pretext for extra claims, which if permitted might make serious inroads upon the United States Treasury.

Competition was spirited in bidding for the work, and it was let for a lump sum to contractors on terms which afforded but a small margin for profits. The most of the materials had to be hauled from 1 to 3 miles, from city wharves, brick kilns, etc., and to surmount on the route an elevation of about 300 feet. Two years were allowed for the completion of the contract.

The cement, brick and marble brought to the work were variable in quality—the marble in both quality and workmanship; in round numbers, about 20 per cent. of each had to be rejected. It may be said here, as one of the points to which attention will be called later, that the rejected cement and brick as removed from the work were understood generally to have been disposed of and used in construction in the City of Washington. Marble which was rejected for defective workmanship only was made good as far as practicable, but being dimension stone it was not easy to remedy the defects. The requirements for cement were, "best imported Portland," and the tests established at the commencement of the work were:

For fineness—To pass a sieve of 2 500 meshes, with a residuum of not over 5 per cent.

For set—Neat, the initial set to be in not less than twenty minutes.

For tensile strength—For seven days, 360 to 375 pounds.

The tests for domestic cement were:

For fineness—To pass a sieve of 2 500 meshes, with a residuum of not over 8 per cent.

For set—Neat, initial set in not less than twenty minutes.

For tensile strength—Neat, one day, 40 to 50 pounds; seven days, 90 pounds.

It will be seen that slow-setting cements were wanted.

These tests were not rigidly adhered to. The impossibility (as claimed by the contractors) of procuring cement in quantities neces-

sary for carrying on the work uninterruptedly, that would bear the tests, induced some modifications of them; as, for instance, if the degree of fineness was not quite in accordance with the requirement, and tests of the same sample showed a satisfactory set and an excess of strength, the cement was accepted. Later on, as the works neared completion, a further modification of tests for the domestic cement was made, as will be again referred to. The domestic brands were mainly used.

The specification for brick was for "best common hard-burnt brick, of good shape," a sample of which was presented at the Navy Department prior to the letting of the contract.

It may be inferred from this brief description of the work, specifications, contract and materials to be dealt with, that some considerable care and responsibility devolved upon the Superintendent. It is one of the disagreeable duties of an engineer to look after defects and failures as well as successes; there is professional profit in it, if no other consolation. It is proposed to enumerate some of the difficulties met with. First and foremost, and throughout the entire course of construction, was the cement difficulty. The cement first used was the Portland, in the concrete foundations. Six different brands were tried; they are among the best brands in ordinary use. After careful testing only two were retained. Preliminary to testing, it was desirable to know the age of the cement. This, in no case, could be ascertained; when shipped, how long it had lain in warehouses, and what exposure it had encountered, were all unsolved problems. The general reputation was ascertained as far as practicable before ordering it, by referring to other works where it had been used. Then followed the tests. It was expected that full weight of barrels and a reasonable uniformity of quality would be obtained. It was found that the numerous barrels weighed, of three different brands, ranged from 368 to 402 pounds net, making differences of 34 pounds; the average weight was 378 pounds per barrel, the deficiency being 18 per cent. under the standard weight of 400 pounds net. This irregularity was not so troublesome as the variations in quality; deficient barrels could be replenished when they were liable to cause material differences in the proportions due to batches of mortar or concrete. The loss of weight fell upon the consumer. The fineness of this cement was quite even, and mostly within the requirements of 5 per cent. The initial set was extremely variable; the extremes were from five to one hundred and twenty minutes; the general range was from seven-

teen to sixty minutes. The set with heavy wire was from sixty to two hundred and forty minutes; the initial set with sand, 2 to 1, was two hours and forty minutes to three hours and fifty-one minutes. The general difference in initial sets, between neat and 2 to 1 was about two hours.

In tensile strength it followed a similar irregularity. One-day tests, neat, gave from 50 to 200 pounds; general average, 108 pounds. Seven-day tests (the lowest of a few) 86 pounds. The general range of lowest, 322 pounds. Average of all, 369 pounds; the highest of a very few, 700 pounds. Two to one tests for seven days gave 150 to 280 pounds, with an average of 188 pounds. A few twenty-eight-day tests gave 405 to 670 pounds. Water (applied, of course, in accordance with rules laid down by the Committee of the Society) varied from 19 to 30 per cent.; the general range was from 25 to 30 per cent. Of the two best brands used one took much more water than the other. Of course, with such a record, a good deal of the cement had to be rejected. The rejections were principally for too quick setting. A large amount of labor was required in testing. As it was impracticable to fully test every barrel, some were taken (except in a special case to be mentioned) with only a test for a set.

Coming to the domestic cement, of which much larger quantities were used, the difficulties were still further enhanced. Eight different brands were obtained, but as they fell out of the ranks from time to time on being tested, only one brand was continued in general use. This was a cement which is very largely used in the City of Washington in both public and private buildings. It is from the upper Potomac, and when good, is exceedingly good; there is but little choice between it and Portland for ordinary work. It is unfortunately very variable, fluctuating between the best desirable quality and a quick-setting or weak material. The fault can only be attributed to carelessness and indifference in its manufacture. It would seem that there is no spur to better efforts, from the remarkable fact that much of it is used, taken upon trust by consumers without testing, or with inadequate or unreliable tests. This refers to a previous remark as to the use of cement which was rejected at the Observatory work.

Among other brands that were rejected as falling short of the moderate requirements made was a New York brand, one that has borne a good reputation and has been extensively used, but an entire cargo of it,

shipped for the Observatory work, had to be rejected. It was thoroughly tested, as the importance of the case required, but it would not meet the requirement, barely reaching a tensile strength of 20 pounds on a one-day test. Thinking that the transportation by water might have had some effect upon it, the author had a sample expressed by rail from New York; it was received in apparently good condition and was tested, but it showed no improvement. Again as much of it was coarsely ground, a sample was screened out, using only the finest material, with the same result. A peculiarity of the cement was a sprinkling throughout it of fine particles of unconsumed coal. It set neat in eighteen to seventy minutes, mostly in thirty to seventy minutes; the tensile strength, one day, was 15 to 25 pounds, average 20 pounds; the strength for seven days was 26 to 100 pounds, average 51 pounds. Water used in briquettes 33 per cent., with but little variation.

The Navy Department was so desirous that no injustice should be done in the matter, that an expert was employed from the Navy Yard who devoted a good deal of time in making tests wholly independent of mine, and his tests confirmed the tests I had made. The author wrote to the agent of the cement company in New York to inquire if he could not supply cement with a guarantee that it would stand the moderate tests required. His reply was that he would cheerfully do so, if the tests were made in New York. As this was an impracticable condition no more came of it. The history may be completed by adding that the author was informed at the office of the Inspector of cement and asphalt for the District of Columbia, that the best quality of Rosendale cement was seldom sent to the Washington market. It will also be not out of place to say that the District Commissioners prescribe a lower test for Potomac cement than for Rosendale.

To return to the Potomac cement; several thousand barrels were used; the consumption at the greatest was about fifty barrels per day, and the perplexities attending its use were great. In general there was a scanty supply, the contractors were wary about laying in a large stock; and as this precaution was not diminished as the testing progressed, the consequence was that the work had to be slowed up, and sometimes brought to a standstill, to await the delivery of further supplies and give time for testing. The necessity for unwearied and uninterrupted tests will be seen from the results that were obtained. The requirements for the cement have been stated; as a rule it was used in mortar

of two parts of sand to one part of cement, and a quality of mortar was wanted that could be used (except in some cases of slow-setting Portland) in half an hour from the time of mixing, and thus avoid the liability of a set intervening with the necessity of remixing and the attendant deterioration.

The average weight of barrels was 280 pounds net, varying from 256 to 334 pounds, making an extreme difference of 54 pounds. The net weight as a whole was 7 per cent. below the standard of 300 pounds. A small portion was furnished in bags, the weight of which held out in full, as they generally weighed 150 pounds—two bags being the equivalent of a full barrel. Samples were tested that would show an initial set of three to ten minutes, sometimes with a moderate tensile strength, and then again wholly worthless; entire lots had to be rejected. A delivery of two or three hundred barrels would occasionally run quite uniformly, of excellent quality, and then be followed by the previous kind. It was remarkable how suddenly these transitions would occur. It required much watchfulness to detect the turning point. The manufacturers, when this state of things was pressed upon them, would make an effort to supply better material; it would succeed temporarily and soon fall off again; mixed supplies would reappear and these would fail in quantity as well as quality. Before the culling process of testing could be completed exhaustion would be near at hand, and delays of work would ensue before another arrival, or before it could be tested, etc.

The alternative was often unpleasantly presented of straining a point to help the contractors along, or to incur their complaints of a too stringent enforcement of rules. Quantities of rejected cement would accumulate and it looked to them like a hardship to be prevented from using it and to be obliged to incur the expense of hauling it away. As one difficulty was with quick-setting cement it was permitted to be used, with the restriction of using the mortar in twenty minutes after mixing, but it was not easy to obtain a compliance with such requirements. An expedient was tried of mixing 20 per cent. of lime paste with the quick-setting cement to prolong the set. It proved so unsatisfactory that it had to be discontinued; it increased the set but diminished the strength and it was impracticable, with ordinary vigilance, to obtain a proper intermixture of the materials; streaks and blotches of lime would appear in the resulting mortar, which evidently impaired its quality. All the

mortar and concrete used in the work were hand-mixed. It would have been much better if machine-mixing could have been substituted.

The author is glad to be able to bear testimony to the excellent qualities of this cement, which came like angels' visits now and then to the work. The general range of such cement was, for tensile strength, neat, for seven days, 100 to 191 pounds; several samples went up to 200 and 250 pounds; the highest of a few twenty-eight-day tests was 270 pounds. This shows that the manufacturers can produce an excellent article if they make the effort.

So much embarrassment was caused in the progress of the work that, finally, as the walls of the several buildings had reached near the point for topping them out, the cement requirement was reduced. This was in consequence of the expressed desire of the Navy Department to relieve the contractors to the fullest extent practicable in the difficulties they claimed to be laboring under, of procuring cement in quantity and quality called for. It was also important to expedite the work, as the term originally specified for its completion had expired. The author was informed by the Department that the Government engineers on other works were accepting the cement on a test of 30 pounds tensile strength for one day. His tests were accordingly reduced thereafter to that standard. A set of ten minutes had previously been accepted with the conditions mentioned.

Such were the difficulties and perplexities that were encountered in dealing with the cement question. How much of the same kind have been met with by other engineers the author is unable to say, but he cannot suppose that his experience has been exceptional. He has recounted them in order to call attention to facts which are of importance and which seem to be deserving of some method of alleviation. He is aware that there are some builders who are prone to say of their work that it is "good enough," and that a persistent adherence to troublesome rules of construction is "more nice than wise," but the adage that "whatever is worth doing at all is worth doing well," is an old and safe one, and in this age of scientific progress it is scarcely excusable for an engineer to content himself with thumb rule practice for which he cannot render a reason and demonstrate that it is the best the case will admit of; his work must be either good in the fullest sense of the word, or indifferent, and but few, he imagines, are willing that it should be placed in the latter category.

Some points may now be noticed which bear upon the general subject, and which, though perhaps not new, will admit of repetition. These relate to practices in connection with the use of cements and mortars which are draw-backs more or less upon successful work.

*First.—Mixing Mortar.*—The advantages of machine mixing are well known. In hand-mixing the first draw-back is the liability of errors in measuring out correct and uniform proportions of prescribed materials. Mortar men make mistakes which generally happen to be against the proper proportions of cement; the quantity of sand will also vary according to whether it is measured in a wet or dry condition, packed or loose. Next, they fail to intermix the cement and sand thoroughly before adding the water—an important point. Again, they will ease up on the labor required to mix all well together after applying water, and to facilitate the operation will over-dose the water. A further error occurs in assuming that all barrels of cement contain equal quantities. The necessity of a close supervision will be recognized in these particulars.

*Second.—Second Set.*—The mortar is placed on the work with the intention of its being used within a specified time before it has taken its initial set. Masons like it extremely plastic, and before their mortar board is emptied they will make frequent calls to "temper up;" more water will be added with re-mixing, and, if oversight is relaxed the prescribed time of using it will have elapsed and a diluted, weakened and second set material will have been used. The second set is so desirable, and its harmlessness so believed in by masons, that they will obtain it if practicable. Brick can be laid with more ease and rapidity with such mortar than when it is in proper condition. The masons claimed that it was permitted on other work, and that it was an unreasonable restriction to prevent it; that they could do more work and with more ease by the use of it. The author was unable from personal observation of the practices on other works to refute their premises.

*Third.—Laying Brick without Wetting.*—This practice when indulged in is the cause, as much observation and many results have shown, of a large amount of bad work; it is too patent to be remarked upon. Men do not like to handle wet brick; their mortar does not work so well with them; is liable to "run," etc., and it is disagreeable to them. A similar trouble occurs with stone work. Stones heated in the sun need cooling

off with water before laying them in a bed of mortar, and wet stones are objected to as unpleasant to handle and wearing upon the hands.

*Fourth.—Bedding Brick.*—The specifications for this in the Observatory work were, to "lay in full bed of mortar, filling end and side joints in one operation, and well bedded in place so close that nine courses of brick laid wet measure 2½ inches more than nine courses laid dry." This was equivalent to requiring ¼-inch joints. The "bedding at one operation" is simple and easy with skillful masons—if they will do it—but it needed a good deal of persistence to get it accomplished. "Full bed and end joints" was another difficulty hard to overcome—¼-inch joints also. Masons have a habit of laying brick in a bed of mortar leaving the vertical joints to take care of themselves, throwing a little mortar over the top beds and giving a sweep with the trowel which more or less disguises the open joints below. They also have a way, after mortar has been sufficiently applied to the top bed of brick, of drawing the point of their trowel through it, making an open channel with only a sharp ridge of mortar on each side (and generally throwing some of it overboard), so that, if the succeeding brick is taken up, it will show a clear hollow, free from mortar through the bed. This enables them to bed the next brick with more facility and avoid pressure upon it to obtain the requisite thickness of joints. With ordinary interior work a common practice is to lay brick with ½ and ¾-inch mortar joints; an inspector whose duty it is to keep joints down to ¼ inch with cement mortar, will not have an enviable task.

*Fifth.—Grout.*—The Observatory specifications did not recognize this material. The author mentions it because the use of it was strenuously urged by workmen who had been employed on other Government works. Their practice had been in brick work, to lay up the outer courses of a wall in mortar, and then throw mortar in the trough thus formed, following with a libation of water from a watering pot until the mortar was converted into grout; the brick were then filled in. The practice may have some advantages in point of celerity in executing work, but assuredly not in giving the greatest strength and security to it. Grout was formerly much used in masses of stone masonry; thick walls with interiors composed of large and small rubble stones were treated by laying the outer faces in mortar, sealing up the joints and then pouring in grout until all interior spaces were well filled; this practice has become more honored by engineers, in the breach, than in the observance,

and is restricted to such parts of the interior of walls as cannot practicably be served with mortar—such as close vertical joints of heavy courses, etc.

The author made a few experiments, such as limited time and means would permit; they could not be pursued to conclusive results, but may not be out of place. At the commencement of operations sand of good quality for mortar was not available; it contained so large a proportion of earthy impurities, as loam, mica, red clay, etc., that it could not be used without washing. A better quality was sought and was obtained from a greater distance, being from the drift of the Potomac River. To avoid the expense of washing, an experiment was tried to ascertain to what extent impurities might be admissible. A sample of well-washed sand was taken and tested in mortar of two parts sand to one of cement; next, a sample with the same cement and an intermixture of sand with 18 per cent. of clay, and the result was, curiously enough, that the latter gave slightly more tensile strength than the former; this might have been accidental, though similar instances have been reported by experimenters. Without elaborating, it was concluded that good sand might be tolerated when not containing more than 10 per cent. of ordinary impurities.

For "second set" several trials were made—not that they were considered necessary, inasmuch as the matter is believed to be safely settled by existing knowledge in regard to it. Mortar that had taken its initial set and was remixed with the addition of more water, was found to lose about one-half the tensile strength due to it if used in proper condition. In the case of domestic cement there was but a trifling gain in strength in seven days over the strength of one day. With Portland cement the gain was better; it indicated a better result in time than the domestic. More experiments in this respect are desirable.

*Mortar made at different Temperatures.*—From the trials made it could not be found that there was any material difference in quality, whether mixed in a temperature of 50 or 60 degrees, or a temperature very near the freezing point. Some cold mixtures showed a trifle better than warmer ones. Some stress is laid upon the question by experimenters, and it seems desirable that the investigation should be extended so as to settle many points that arise under the necessities and ramifications of practice with mortars in our climate.

*Deterioration by Age.*—A test of domestic cement showed that the

time of set was doubled when one year old. Tests made of a barrel of Portland (date of manufacture not known) showed in an interval of time of nine months between tests, 80 per cent. increase in time of set, but no loss of strength between the seven-day tests of the two periods. Was the latter an accidental result?

*Testing Cement.*—The rules formulated by the able Committee of the Society upon this subject have been of great service, but there are a few points in connection with them which the author thinks many engineers would like to have more fully elucidated. It is mostly a question of manipulation and machinery. In order to make tests that all manipulators can compare with each other, it is important that they have the means of producing uniform and unvarying results. This, unfortunately, is not the case. Tests of one party differ from those of another, when made on exactly the same cement. The trouble known as the "personal equation" comes in and no practicable means have been devised to eliminate it. It enters into all the processes of mixing, applying water, filling moulds, immersing, the use of the testing wires, breaking briquettes, timing operations, etc.

The author has had some perplexing questions arise (as doubtless have others) from differences between his tests and those of experts who have operated with the same brand of cement. A decision affecting the quality and acceptance of a brand must sometimes be made under these circumstances. In one case that became questionable it was found that an expert had departed from the Society rules, in the one point of quantity of water used, and the tempering prescribed for his sample. This is believed to be the cause of many discrepancies that occur. From a large number of comparisons made by the author, in his practice, of the results of testing the same brand of cement under the same circumstances, the personal equation gives a considerable percentage of uncertainty as to the true quality of the material.

The mechanical devices in use are not as perfect as it is believed they can be made. A clutch which was used by the author for some time gave a fracture of the briquette at a point not at the weakest part, but at the sides of the briquette that were impinged upon by a too narrow point of the clutch; one-half or more of the briquettes developed this fault. He substituted another clutch with broader surfaces in contact and had very few failures afterward, in the proper fracture of briquettes at the narrowest point.

These difficulties have of course not escaped the observation of other members of the Society. They show the necessity of the exercise of much care and good judgment in passing upon the quality of cement. The author took occasion, for the purpose of a check, to follow up some tests; through the practical results obtained in construction the quest was somewhat involved; it embraced not only the contingencies due to the personal equation, but the shortcomings of mortar makers and masons already alluded to. The tests were desultory and inconclusive for the want of time and assistance in conducting them. With two aids as inspectors, whose time was taken up with more important duties, but little attention could be given to experimenting. Mortar was taken from the work as it was being used, the previous instrumental tests of which, together with the subsequent operations it had passed through before reaching the work, time, etc., being noted; it was then tested and the results compared with the previous ones. It must be said they were not reassuring or satisfactory. Without going into details it may be said that the set was very much prolonged and the tensile strength was impaired from what it ought to have been. What was previously remarked as to the habits of mortar mixers and masons the author thinks principally accounted for the results. It was a spur to greater vigilance as well as an illustration of one more of the contingencies that beset the pathway of the conscientious (shall we say overconscientious?) engineer in his efforts to insure good work. Tests of this kind will probably surprise those who make them in a thorough manner.

Some builders still use cement without instrumental tests as at present in vogue. By what means they determine the quality of the material the author is unable to say. Some years ago, as for instance, during the building of the old Erie Canal, and later in the enlargement of the canal (of which latter work he had some cognizance as a younger man than now), the tests were about as follows: For ascertaining the presence of quick lime in cement, a specimen was tasted, and also tried by a small ball mixed with water, which, after remaining a few minutes in the air was immersed in a tumbler of water; if it did not effervesce and immediately fall to pieces it was supposed to be free from lime. Also, if it kept its shape and showed signs of hardening in a few days, it was regarded as a favorable symptom of its strength. A further trial was made by placing mortar (usually mixed two to one) between two spawls and immersing in water; if at the end of two

or three days the mortar had not dissolved and run out, but showed a light film or crust on the surface, indicating the process of induration, it was held as safe for use. Fineness was mostly determined by rubbing a pinch of cement between the thumb and finger. Besides this, barrels were looked after to see if they were not damaged by exposure, causing discolorations, lumps, etc. It should be added that pats were made of cement which were broken after time was given for a full set. The author does not recollect that much cement was rejected. Later tests of General Totten and others followed, employing the loaded wires, and other means, breaking parallelopipeds, etc., until present methods were perfected for which due credit should be given to General Gillmore and other members of our Society.

Evidences of the quality of work are sometimes referred to by labor-saving persons, after the work is done, by probing mortar with the point of a knife, driving a nail into a joint, etc. Such proof may be satisfactory (supposing it to be successful) when applied occasionally as a check during the progress of work, but it is scarcely reliable and may be very misleading if not antedated by better tests.

### Concretes.

Several experiments were made with concretes—difficulties being encountered with cement as before noted. The materials were, mainly, Portland cement, good sharp sand, broken stones (the latter specified to be "not over 2 inches in any way") and clean gravel. The broken stones, when not clean, were required to be washed; they were from sound gneiss rock, with some fragments of white quartz. Mixing was thoroughly done with careful attention to the use of water and tempering. As used in construction, batches were made with one barrel of cement, and the concrete was deposited in layers of 6 to 8 inches in thickness, and rammed until a show of water appeared at the surface. The experi-

The author has alluded to some old fashioned modes of testing cements which prevailed during the construction of the New York State canals. It will be proper to note the character of the works executed. Although the better modes of testing cement now in vogue were not then employed, yet the care and good judgment exercised by the engineers enabled them to construct some of the best specimens of hydraulic masonry that are to be found in this country; the locks and aqueducts of the eastern division of the Erie Canal are notable examples of this character. The eastern division—from Little Falls to Albany—is spoken of from personal knowledge, the author having commenced his engineering experience on the "enlargements" of that portion of the canal under John B. Jevois and William J. McAlpine.

Other portions of the State works exhibit equally good construction by other engineers of the period. Those old Romans of the profession have since joined the great majority, and have been gathered among the old builders who "builded better than they knew."

ments were limited principally to combinations of different proportions of ingredients and noting the results. They afford nothing particularly new, but may add something to the common stock of knowledge which we possess in regard to this important material. The author submits briefly and in condensed form, the prominent results.

The study of the best proportions and combinations of ingredients for strength and solidity, and at the same time keeping an eye to economy, is one of well-known importance. Uniform rules cannot be established, for the reason that materials are variable and cannot be obtained in all cases of equal quality; experiments can therefore give only approximate aids in the matter, showing what results may be obtained under stated conditions and circumstances. The author regrets that he is unable to give results of more value, such as might be obtained by the use of machine-mixing and machine-broken stone, etc. Trials were made with blocks formed in moulds of 12 x 12 x 6 inches, containing one-half of a cubic foot; some of the results shown were also obtained from large quantities of concrete as used in the work. It is absolutely necessary in making and using concrete, to have it under the eye of an inspector.

The following tabular statement sums up the chief points resulting from these experiments. The initial letters in column 2 are: P for Portland, D Domestic cement, S sand, Gr. gravel, St. broken stone; and the accompanying figures, as P 1, S 2½, etc., give the different proportions of materials used.

It was mentioned that a special description of concrete was required in the Observatory work. The purpose of this was to meet an astronomical necessity of obtaining a homogeneous mass of material in monolithic form that would be stable and subject as little as possible to atmospheric and other influences. Trouble had been caused in the old Observatory by reason of the telescope resting upon a foundation that proved a failure in these respects; the vision was disturbed by changes that occurred in the materials composing the foundation, caused, as supposed, by different temperatures and other conditions of the atmosphere. The base was a structure of stone masonry. It was proposed at first to construct the new work of béton, but it was settled to make it of concrete, as a cheaper material and equally good. Four separate foundations were required, in as many separate buildings. The drawing (Plate LVII) will illustrate the form and dimensions of the work. The buildings in which they were enclosed are shown as numbers 1, 2, 6 and 7.

| 1. No. of Sample. | 2. Materials and Proportions. | 3. Age of sample when tested. Months. | 4. Weight of half cubic foot after a long set, as per Column 3. Pounds. | 5. Time immersed for full absorption. Hours. | 6. Absorbed per cent. of weight of Column 4. | 7. Weight per cubic foot when saturated. Pounds. | 8. Voids per cent. of volume after long set. | 9. Quantity of concrete made from one barrel of cement. Cubic yards. | 10. Cost in work per cubic yard. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | P, 1; S, 2½; Gr., 3; St., 5. | 5½ | 67⅛ | 1½ to 2 | .030 | 139 | .030 | .... | .... |
| 2 | do | 4½ | 68½ | 2 to 2¼ | .029 | 141 | .064 | .... | .... |
| 3 | do | 4½ | 67⅜ | 2 to 3 | .020 | 138½ | .048 | .... | .... |
| 3½ | do | 5 | 73⅓ | .... | .... | .... | .... | .... | .... |
| 4 | P, 1; S, 3; Gr., 4; St., 7.. | 7 | 68⅛ | 2 to 3 | .037 | 141⅛ | .080 | 1.65 | $4 67 |
| 5 | P, 1; S, 3; Gr., 3; St., 7... | 8 | 71½ | 1 or less | .028 | 147 | .064 | 1.36 | 5 50 |
| 6 | P., 1; S, 3; Gr., 4; St., 7.. | 5½ | 72⅛ | 1 or less | .028 | 148½ | .064 | .... | .... |
| 7 | do | 4¾ | 69¼ | 1 | .029 | 142½ | .064 | .... | .... |
| 8 | P, 1; S, 3; Gr., 3; St., 7.. | 8 | 70 | 1 or less | .025 | 143½ | .056 | 1.36 to 1.44 | .... |
| 9 | P, 1; S, 3; Gr. 5..... | 3½ | 69 | 3 | .043 | 144 | .096 | .... | .... |
| 10 | P, 1; S. 2½; Gr., 3;St., 9.. | 9 | 66⅛ | 1 to 1½ | .030 | 136½ | .064 | .... | .... |
| 11 | P, 1; S, 3; Gr., 3; St., 8. .. | 9 | 70¼ | 1 or less | .032 | 145 | .072 | .... | .... |
| 12 | D, 1; S, 2½; Gr., 3; St., 9. | 8½ | 65 | do | .054 | 137 | .054 | .... | .... |
| 13 | P, 1; S, 2½; Gr , 3; St., 4½. | .... | .... | .... | .... | .... | .... | .... | 6 87 |
| | | Some Formulas used on other Works: | | | | | | | |
| *A* | P, 1; S, 2; Gr., 3; St., 4. . | Washington Monument. | | | | | | | |
| *B* | P, 1; S, 3; St., 5..... | do | | | | | | | |
| *C* | D, 1; S, 2; St., 4..... | do | | | | | | | |
| *D* | P, 1; S, 3; St., 5. ..... | Prescribed by District Commissioners, D. C. | | | | | | | |
| *E* | do | do by Architect of Congressional Library. | | | | | | | |

Nos. 10, 11, 12 and 13, above, not much used; No. 9 was for roof.

The foundations, as will be seen, were deep; the material in which they were excavated was a firm clay, with some gravel irregularly interspersed through it. It was supposed that a depth of 12 feet might be required for the concrete, but a good foundation was found for it at a depth of 9 feet. The pits were dug with perpendicular sides, and the concrete was put in, leaving a space of 6 inches around it, which was packed with clean sand as the work was carried up. The object of the sand was to relieve or check such vibrations or jars as might from any exterior cause reach the concrete mass through the surrounding clay.

In order to make a concrete as homogeneous as possible, the following mode was adopted: The cement was of a good quality of Portland, but it was impracticable to procure a brand that was even and uniform in set and tensile strength. Each barrel was tested, and those from the lowest admissible quality and upward were accepted. Then, as it took ten barrels to make a complete layer of concrete 6 inches thick, each ten barrels used were spread out on a broad platform and thoroughly intermixed. This produced a uniform quality for each separate layer. It was impracticable to carry the process of intermixing beyond this; it secured the homogeneousness purposed for each layer in itself, which was the best that could be done. After intermixing the cement it was measured back into barrels for use. For greater assurance as to the success in intermixing, samples of the mixture were tested and compared with the average tests previously made of each ten barrels. The tests of tensile strength corresponded in the two cases within 2 per cent. The mean of several tests gave a strength, neat, of 430 pounds. Broken stone of uniform quality was selected, but as it was not regular in size the largest were thrown out, and all portions of the size of ordinary gravel, together with all crushed and finer material, were screened out. Gravel was taken to supply the place. The proportions of materials were:

1 part Portland cement, 2½ parts sand, 3 parts gravel, 5 parts broken stone. Tests of this formula showed a filling of voids within 6 per cent. of the whole volume.

In carrying on the work each layer was completed before commencing another, and time was afforded for a layer to attain a strong set before working above it, and before depositing a succeeding layer the surface of the preceding one was sprinkled over with a film of dry cement. No layer was left unfinished over night, and the work was pro-

tected when left for the day, or when it was intermitted on account of weather. It is to be observed, that owing to the variable qualities of the cement, there might have been (without the precaution of intermixing) in various and irregular portions of each layer of concrete differences in strength amounting to 40 per cent. The weight of the concrete, as determined by many samples in blocks of 12 x 12 x 6 inches, was, after a long set, and when quite dry, 136 pounds per cubic foot. One barrel of cement of 380 pounds net, made 1.18 cubic yards of concrete. The method adopted of intermixing each ten barrels of cement prevented any material difference in strength between the layers. The film of cement between the layers was found by experiment to combine them thoroughly together into one inseparable mass.

The cost of intermixing was twelve cents per barrel, and the cost of all was $6 per cubic yard. This applies to the main blocks before the supplementary small piers were added. These piers, five in number on each block, are indicated on Plate LVII; they were truncated in form and 10 feet high, capped with granite, the tops reaching the floor level of the enclosing building. The buildings were of corrugated iron, this material being used as well for fire-proof purposes for security of very costly instruments, as for the purpose of enabling as uniform a temperature as practicable to prevail inside and outside the structures. No provision could be made for artificial heating, as the astronomical observers have to dispense with such conveniences without regard to the weather.

A good many trials were made with concretes besides those given in the previous tabular statement, but they are omitted, and such only are presented here as had reference to the work as executed. It will doubtless be seen, on comparison, that more economical formulas are adopted on some other works.

The object in the publication of these notes will be attained if a few practical results shall grow out of the effort. A glance at the results desired, and the necessity of obtaining them, will be proper in conclusion. The author has before him a list of failures and disasters which have occurred in public and private buildings within a few years past, in which many millions of dollars were involved, as well as some loss of human life, all traceable directly to defective construction, bad workmanship and bad materials, mortars and cements conspicuously included. The author does not include cases where the omission of

mortar and lax supervision have been disastrous. It is unnecessary to cite examples or to extend the catalogue. This can easily be done by all observing builders; non-professional individuals are only too familiar with them. As for instance, let them be asked to recount their costly experience in one form or another in remedying faults of construction, repairing defacements due to yielding foundations, such as cracked walls, derangements of plumbing and other interior work in buildings they have occupied and trustingly purchased, and if the list is footed up the sum total will appear in a convincing form. We cannot shut our eyes to the Protean forms in which these things occur. They are an offense to all good workmen, to all good builders, engineers and architects. Is it practicable to avoid them, and by what means? We deal here with the so-called "soul of masonry"—mortar. How shall we begin?

The author makes a few suggestions with deference, much preferring that they should come from other members of the Society. He would propose to start at the origin—with the manufacturers of cement. Cannot these be induced in some way to produce a material of less variable quality and of a higher standard? Imported cements could be labeled so as to give a reliable indication of their quality, date of manufacture, etc., with a guarantee of tests they will bear, say up to a stated age. If this cannot be done, then let the product be accompanied with a scale of prices for their agents, proportioned to its real value after the consumer has been at the pains and cost of laboriously testing it. Our domestic cements should be similarly treated; no one will doubt the practicability of doing it. We have the raw material in superabundence in all parts of the country; with proper care by experts in selecting, burning and grinding the material, an excellent quality can be obtained. Results have shown that when this is done we need have but little occasion for the use of the foreign material. Except for a few special purposes, the author believes we use much more of the latter than necessity or economy requires.

It is quite certain that if no complaint is made by engineers and architects there will not be much improvement. If builders in general will consent to the use of the promiscuous and variable brands that are found in our markets, without discriminating tests, and without seeking a higher standard, the standard will not be raised.

In testing cements there is a good opening offered to skillful inventors in the improvement of mechanical and other devices for proving with

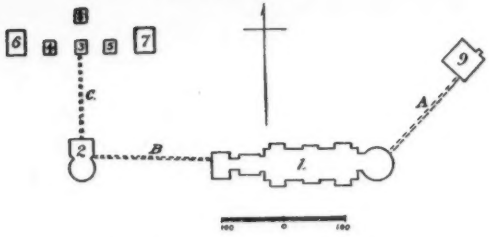
less doubt and uncertainty the value of cements and mortars. The "personal equation" should be eliminated. A valuable rule would be such an one as would govern a variable practice of accepting tests of one day, seven days, etc. Also, as to the acceptance of cement in large lots after testing one barrel out of ten, or twenty in one hundred or more. Such tests and acceptances it is believed are not uncommon. The author has been much puzzled in trying to apply them with a due regard to the doctrine of chances. In mortar making there is room for improvement. It is questionable whether all mortar and concrete should not be required to be machine-mixed when used in more than certain small quantities.

*Grout, Wetting Brick, etc.*—The mode of laying brick would admit of some useful rules in regard to practices which have been mentioned, especially in the use of grout. The ordinary method of wetting brick is deceptive; by throwing bucketfuls of water over a large pile, it reaches a few brick on one or more sides and escapes many. When it is known that a dry brick will absorb 6 to 10 per cent. of its weight in water, and requires four or five minutes for the process when immersed, the futility of common methods or subterfuges can be realized. Immersion is the only sure method to avert the evil consequences that are well known. These are only mere hints. More could be, but probably more than enough have been given. The author trusts he has not exaggerated their importance, or unduly pressed them upon attention.

To prosecute investigations such as have been alluded to requires not only labor and skill of a high degree, but an outlay of means for laboratory and other appliances, which latter necessaries are not a part of the endowment of the Society. But few engineers amass fortunes in the practice of their profession, although ample qualifications in other respects are not wanting, and it would be an onerous tax upon them to be required to explore exhaustively all the questions of scientific interest that are presented to them in their calling. Testing machines of great utility, involving large outlays, have been made by outside parties, and with Government aid, for the advancement of knowledge in the use of iron, steel and other building materials, and liberal contributions have been made by philanthropic individuals to the Society for other purposes. We regard these of course in an appreciative spirit, but may we not hope that the good work is not yet ended?

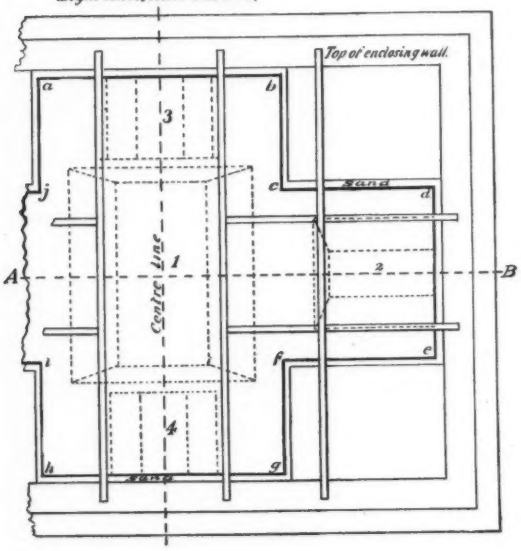
The author recently met with a remark which is as applicable to this

*General Plan.*

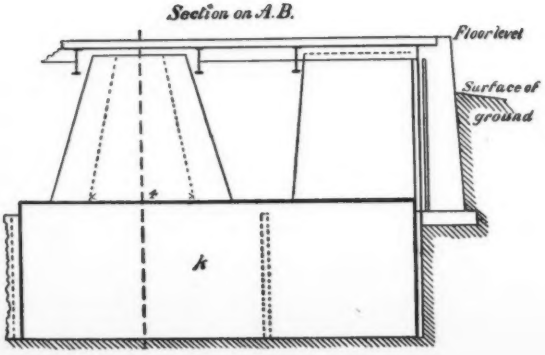



*Part Plan of Concrete Foundations.*

*Heavy lines, outlines of Main Block as a.b.c.d.e.f.g.h.i.j.k*
*Dotted lines, on Plan, outlines of Supplementary Piers 1.2.3.4.&c*
*Light lines, other details.*




*Section on A.B.*



topic as to the cause for which it was so fittingly made. The writer* was referring to the propriety of public and private aid in prosecuting bacterial investigations, and says:

"It is a pity that some of the large-hearted men in this country in whose hands great fortunes are placed for a little while, do not see to it that suitable endowments of research in this most promising field are furnished here." * * * "There has never been a time in the world's history when well-directed and well-sustained scientific research promised so much of positive and direct benefit to man as it does here in this under world of life to-day."

## DISCUSSION.

J. FOSTER CROWELL, M. Am. Soc. C. E.—I have nothing to offer of my own that is of any value, but I think the author of this paper is entitled to a great deal of praise for the way in which he has treated the subject. He has gone much deeper into it than usual, and has indicated one of the greatest difficulties that engineers enconnter in securing perfect work. It makes no difference how good the cement may be or how well tested, if it be not combined properly with the other materials. The author has suggested that all mortars should be mixed by machinery, and that is one way of saying that the mixing of mortar should be looked after quite as carefully as the manufacture of cement. He speaks of the difficulty due to the personal equation in testing cements. I don't suppose anybody could ascertain the personal equation of the average mortar mixer, on whom the engineer must depend—in ordinary contract work. It seems that the Government or other parties having such very important ends in view—as the author describes in this case, should deviate from the contract system in this kind of work. A contractor cannot be reasonably expected to follow such rigorous specifications, and the engineer will always have difficulty in getting by contract the degree of excellence required by them. I think that one remedy for defective work in masonry would be found if the specifications covered all details of mixing as well as of material; when this is done, and tests are applied to the mortar used, I think we will begin to get much better work than we can secure while we confine ourselves to rigorous cement specifications alone.

JAMES OWEN, M. Am. Soc. C. E.—There is one very important question in the setting of cements, namely, that of time. Take a mass of masonry, say 7 or 8 feet thick, I would like to know how long it will

* "Glimpses of Bacteria," by T. Mitchell Prudden, M.D., in *Harpers' New Monthly* for April 1st, 1891.

take for the cement in the bottom of such a wall to arrive at its ultimate setting point? Some years ago I had to examine a masonry wall that was poorly laid, and I took some samples of the mortar from the interior. The wall had been built about four months, and the mortar was so poor that I condemned the wall. I took this sample of mortar to my office, and put it in my desk; some three or four years afterwards I came across it, and it was thoroughly hard and perfect. That shows that the question of time should enter in. In another case where I had to examine a mortar that had been in a wall some seventeen years, I found that it had been water-logged and had never set at all. It seems to me that the specified requirements for a cement should be adapted to the class of work that the cement is to be used for. The cement used for water works, for example, should have a more rigid standard than for ordinary masonry. The most important point is the question of time, how long will it take the cement to set, so as to give the strength required in any given case?

CHARLES B. BRUSH, M. Am. Soc. C. E.—It is perfectly true that there are remarkable features which cannot be explained in some grades of cement. It is also perfectly true that manufacturers start out and make a very excellent grade of cement for a long time, but do not always adhere to that same high grade. I believe it is true, however, that if an engineer has the reputation of insisting upon a certain grade of cement, and if he will deliberately keep on rejecting the cements submitted until he gets the grade that he wants, my experience is, it will save him a great deal of trouble, and the manufacturer also. I do not mean that he shall stand upon any petty point, but he can prescribe the grade of cement, and by insisting upon it, that grade will be furnished him. In the Dock Department for a long time all kinds of cement were furnished, until the Department decided what grade of cement they would take, and since then that grade has been furnished. If it is felt that from fear of delaying the work, or from complaints of that kind, the engineer will give way, I think he will always have a great deal of trouble in getting a proper cement. A great deal depends upon the firmness of the engineer in charge of a work.

The CHAIR (A. Fteley, Vice-President).—What is your opinion in regard to the tests of neat cement as against tests of cement and sand?

Mr. BRUSH.—I think both tests should be used. I do not think you should rely upon the one or the other; I do not think you should take any one test in regard to cements. As to the question Mr. Owen has raised, how long a cement keeps on setting. Some cements set more slowly and some more rapidly; that depends on the mode of manufacture and ingredients. I do not think either neat tests or sand tests alone should be relied upon; I think both should be taken.

The CHAIR.—In work which requires a very large amount of cement, and where, in justice to the contractors, it is necessary that the cement

should be tested properly and an answer given promptly to the contractor—do you not think that the quick test of twenty-four hours with neat cement is highly desirable; not because it is the best test, but because, having established a standard for your cement by such a test, you can tell that the cement which you want will, after twenty-four hours, give you so much, and by repeating that test on a large number of barrels, you can tell whether you will take it or not?

Mr. BRUSH.—I do not think there is any question about it. I think that as soon as the cargo comes, the contractor should be informed what the result is as to that cargo. If the same person has made all the tests, as should be the case, it is really a question of comparative results. If the results during that twenty-four hours are favorable, the contractor should be informed so that he may proceed, subject to later tests; a contractor should not be held back with a large cargo.

I would like to hear from Mr. Myers, who has been giving a great deal of attention to the subject. I know that a great many different grades of cement have been offered to the Park Department and that they had some difficulty in relation to them; but my impression is that by firmly adhering to the position that he would have a cement which was satisfactory, he always got it.

C. H. MYERS, M. Am. Soc. C. E.—I can only say that we always required the cement to reach our standard, and if it did not show according to the ordinary tests that it was up to that standard we rejected it, and other cement had to be furnished which came up to the standard. Sometimes a brand that had been giving favorable results would not answer the tests; we concluded that there was some defect in that particular lot and rejected the lot; at another time the same brand might answer the test at once. Sometimes a new brand would be furnished and the same procedure followed until it gave the cement we wanted.

Mr. BRUSH.—Did you not always succeed in getting the grade you wanted?

Mr. MYERS.—We always did, and I might add that, as an indication of the ability of cement makers and dealers to supply a required grade of cement when effort is made to do so, we experienced less difficulty in obtaining what we wanted after the requirement for tensile strength was considerably increased than we had had previously.

F. COLLINGWOOD, M. Am. Soc. C. E.—I think from what Mr. Brush says he would qualify it by saying that all cements should be subject to a long time test sufficiently often to be sure that it is sound. Some cements will give great strength in a short time, but lose strength afterward.

Mr. BRUSH.—I understand that. The long time tests would prove the results. I would like to have our Chairman give us some of his experiences.

The CHAIR.—I beg to be excused from giving my views on this subject for the present. One of the troubles with all cements is the presence of free lime, and in this connection I might mention a fact which I have seen in a published report by Mr. George F. Deacon in connection with the building of the Vyrnwy dam. Portland cement was used there, and Mr. Deacon, having recognized the presence of free lime in almost all the Portland cement that he bought fresh from the factory, found it necessary to organize a system by which he could get rid of it. In order to do that he built a large frame building, with seven galleries or shelves all around on the inside. The floors of these galleries were formed of movable slats, such as we use for blinds; these were each moved by a single lever at the outside of the building. Supposing these floors to be covered with cement, each floor holding about one day's supply; the first used would be always taken from the lower shelf; at the end of the day, by opening the slats, the cement on the second shelf was dropped on the lower, the cement on the third shelf was dropped on the second, and so on, leaving the top shelf empty and ready to receive a load of fresh cement. In that way the cement had been handled and exposed to the air seven times before it was used. Every day the amount of heat developed by the mixture of cement was recorded, and it was found that each day of this treatment lessened the temperature of the mixture about one degree until it was finally acceptable for practical purposes.

Mr. COLLINGWOOD.—This process of seasoning cement is very fully described in the specifications for a bridge across the Seine at Rouen, in which it was provided that the cement was to be delivered in certain quantities at certain times, and spread over a large floor, protected from the weather, there to remain long enough to thoroughly slake all free lime. None was allowed to be used without undergoing this exposure to the air.

ARTHUR S. C. WURTELE, M. Am. Soc. C. E.—The paper of Mr. Grant is a description of the work of construction of the Naval Observatory at Georgetown, showing the troubles of the engineer in having work done up to specifications. His remarks on cement testing show clearly that the specifications in that matter were unreasonable, in that a very slow setting cement was required and at the same time excessive one-day and seven-day tests; so much so that the requirements of the specifications were finally abandoned to enable the work to be completed. A curious and unjustifiable difference was made in prescribing a lower test for Potomac cement than for Rosendale. Several experiments were made, but the figures were not given, except in a general statement of results which must be indefinite from the small number of experiments. I take exception to the statement that 10 per cent. of clay may be allowed in sand without detriment, and that result seems to be given on a single experiment. In State work I do not consider less than four-day tests,

and I find when they give over fifty pounds breaking strength, with the briquettes clean and smooth, the cement invariably comes up to the specifications for seven and twenty-eight day tests. Less than four-day tests are liable to be very variable.

Mr. Grant objects strongly to a variation in the weight of barrels of cement, but I do not know that they are to be expected to be uniform in weight, and attach no importance to such a difference. He also objects to grout. Now my experience is that masonry properly grouted gives better results than without the use of grout. As to the personal equation, the State practice is to have all testing done by the same man and thereby eliminate error on that account, as the error if any is the same in all cements. It is not surprising that mixing quick lime with cement was a failure, but I do not understand how the temperature of the water used made no difference, and think the result is due to too few experiments.

The table of concretes is valuable as showing the results of different combinations. The mixing of ten barrels of cement together for concrete would undoubtedly give a more uniform concrete and is a good precaution where exact results are required. The only way to improve cement is to reject all that does not come up to a fair specification. If a working specification could be settled on it would be advantageous to manufacturers, but it would have to be entirely reasonable, as shown by the abandonment of the specified tests in this case of the Observatory.

The remarks about wetting brick before use are quite correct. Complete immersion of brick is absolutely necessary for good work; sprinkling or throwing water over them is of no use.

D. J. Whittemore, Past-President Am. Soc. C. E.—We can assure Mr. Grant that his experience in using and testing cement mortars is but a parallel to that of many of our members who have conducted similar work and tests. I take it for granted that manufacturers of cements, both foreign and domestic, endeavor to furnish a product both good and uniform in quality, and I can readily surmise why they desire the tests to be conducted at their works, as experience is that results there attained are exceedingly liable to vary to an extraordinary degree from the tests conducted at the place where the cement may be used, even when the tests are similarly conducted at the two places.

Cements often deteriorate in proportion to the number of middlemen through whose hands they pass. The increase in number of such between the producer and consumer indicates added age to the product and sometimes something worse. It is not unknown that some middlemen have occasionally mixed good and bad cements, or even Portland with natural cements, and placed the mixed product on the market under the brand of the best. It is a pretty well established fact that foreign Portland cements deteriorate markedly in transit by ocean to this

continent, and this continues to occur during transit by canal, lakes and rivers to such interior ports as are thus reached and supplied.

I have it on good authority that occasionally, when cements reach their destination in a bad condition, so much so as to be hard, lumpy and difficult to shovel from the barrel, the middleman, after making such settlement as he can for a rebate from the consignor, regranulates or repulverizes the defective cement and places it on sale under its original brand. An instance of this kind brought to my knowledge is as follows : A vessel bound for Chicago loaded with foreign Portland was partially wrecked and the barrelled cement was well wetted. These barrels were delivered on dock on arrival, and were not accepted by the party for whom they were intended, and finally were given to a contractor as compensation for their removal. As much of this cement as could be conveniently pulverized was so treated, sold and used in the market mentioned, as genuine Portland. Another instance that has come to my knowledge within the last few days: Of a cargo of foreign Portland received this season at New Orleans, one hundred barrels were shipped to an important city up the Mississippi and there received by the importer. Sixty of these barrels were found caked, but fortunately the importer was honest and would not allow it to be repulverized and placed on the market for sale.

It is certainly gratifying to our members to notice the complimentary remark at the commencement of Mr. Grant's paper relative to the rules laid down by the Committee of our Society for testing cements; yet as one of the members of that Committee, permit me to say that I wish these rules were more satisfactory in some respects, and in the light of further experience it is my belief that they can be made so. What we fail to secure by these rules is the determination of the absolute degree of plasticity of the mortar to be used in the fabrication of test specimens, and also the absolute pressure required, or desired, in moulding.

Since the publication of these rules several ingenious machines have been devised for moulding, which are intended to secure (and do apparently) uniformity of manipulation. The indications are that Mr. Grant followed the rules laid down by the Committee of our Society closely, yet all experimenters do not do this. Several instances of this nature have lately come to my notice, of *tyros*, having charge of their first work in mortars, who appeared to have the notion that mortar was a nasty semi-liquid mass, and that the only work needed was to lift the same on the spatula or trowel and slush it into the mould, strike it off level and allow it to set with all the water and air spaces in the body of the briquette that such manipulation will permit, and then expect satisfactory results from the tests. Again, cement manufacturers soon determine how to manipulate test samples so as to secure the best possible results, making error in their direction, probably not in degree, that the *tyro* makes in his.

Some years ago my attention was called to what purported to be a very learned paper upon cement tests, published in an engineering journal (not ours) in which some astounding, unique and negative results were shown, and the graphic representation of the strength of cement mortars at different ages shown thereon could well be mistaken for a profile of the Rocky Mountains. It appeared that the cement mortars tested were first moulded and exposed, in the form of a long slab, having a cross-section somewhat the form of a briquette, and when tests were required briquettes of the thickness desired were cut off the slab with a hand-saw.

Opinion hastily formed, and based upon slovenly conducted experiments, is the bane of all scientific work; and it is safe to assert that the results of the first three months' work of a novice in cement testing should never appear in print.

In the report of the Committee on A Uniform Method of Cement Tests, experience has shown that an error was committed in attaching thereto the addenda giving the Committee's opinion as to what strength different cements should indicate. It may be proper to say that this addenda had the opposition of at least two of that Committee, and it was only through the united opposition of these two members that the matter was expunged from the body of the report, with the understanding that it might appear as an addenda, the publication of which has certainly been unsatisfactory to the producers of our natural cements, and misleading as to the strength of Portland when tested as advised by the report. This can be cited as another instance of the ill effects of reporting on matters beyond the specific duty delegated to a committee appointed by the Society. The fact is that at the time this report was formulated, little was known relative to the strength of Portland cements when test samples having a breaking area of 1 square inch are used. The bulk of the tests previously made were from specimens having a breaking area of 2¼ inches square.

In a paper read by me before this Society at the Annual Convention, at St. Louis, several years ago (*Transactions*, Vol IX, 329), it was shown that in tests of different sizes of specimens of the same mortar, the strength varied per square inch approximately in an inverse ratio to the periphery of the breaking section, that is to say that a briquette with a breaking section of 1½ inches square (2¼ square inches area), indicating a strength of 40 pounds per square inch, when tested in briquettes having a breaking area of 1 inch square would show a strength approximately of 60 pounds.

I trust our Society will reappoint a committee upon improved methods of cement tests, in the hope that a better solution of matters that appear indefinite in the former report will be reached, and at the same time methods of testing be devised which will not involve long time delay in determining results. It is quite clear to me that this can in a

measure be accomplished by the use of steam bath exposure to hasten induration, whereby activity and ultimate energy can with a reasonable degree of certainty be determined. This method of hastening activity was used by me some sixteen years ago, and the same process was then and is now successfully used by some cement sewer pipe manufacturers in expediting their work. Henry Faiji, M. I. C. E., one of the most accomplished cement experts of England, has in his London laboratory a device of his design for this purpose.

The varying results of Mr. Grant's tests indicate pretty conclusively that the Portland cement used was, in one respect, that which was called for by the architect's specifications, genuine imported Portland ; as some of it appears to have been subject to a tempestuous ocean voyage or to other equally beneficial treatment before it arrived at the place of use.

In conclusion, I wish to call attention to the fact that our Government exacts a duty on foreign cement, supposed by many innocent-minded persons to have for its object the encouragement of the manufacture of Portland cements in this country; but in this instance the architect, who is also by virtue of his office an agent of the Government, requires the foreign product, thus discouraging any attempt on the part of our citizens to produce such cements in this country ; hence I am forced to the conclusion that this duty is interpreted by the architect to mean *for revenue only*. Our people are paying millions yearly for the foreign product. It is now known to many engineers of the West that we are producing in the interior of our continent Portland cements equal in quality to the very best, and far superior to a large bulk of the foreign product brought to and sold in our country.

W. W. Maclay, M. Am. Soc. C. E.—Mr. Grant's remarks about the superiority of machine-mixed mortar over hand-made mortar are very appropriate, and his objections to the re-tempering of mortar and the use of grout will be cordially indorsed by most engineers.

In reference to the deterioration of Portland cement by age, I am sure, from experiments carried on for a number of years, that Portland cement deteriorates very slowly, a year or two causing practically no loss of tensile strength, although, of course, invariably making the cement more slow-setting. I unite with Mr. Grant in wishing to have some method of cement-testing adopted that will eliminate "the personal equation" of the operator. But while it is difficult to attain this result by our present system, by care and attention it is possible to largely reduce the probability of error, so that, for example, with a trained cement-tester the average differences in re-testing the same cement should not exceed 5 per cent. As I have said in another publication: "It must not be understood that the testing of cement is other than laboratory work, for all attempts to popularize cement-testing so that it can be brought within use of all who use it, have signally failed. Cement tests, to be of any comparative value, will always have to be made by

persons accustomed to accurate methods and possessing a degree of experience and skillfulness in this particular line of physical research, which is only to be acquired by long practice. No great equipment of scientific education is necessary for the cement-tester; but, on the other hand, he must have a large amount of accuracy and practical experience, with the conscientiousness that will prevent him from slighting or slurring over details in order to obtain results." There is one point in the paper in relation to the great want of uniformity in quality between the barrels in the same lot, as experienced by Mr. Grant, from which I beg leave to differ, for the following reasons:

In the manufacture of cement by the grinding and conveying processes, the cement is thoroughly mixed in large quantities, and the quality therefore varies in large quantities, in some relation generally to the quantity produced per day or per week. From the very nature of the manufacture it would be impossible to make cement, varying much in the different barrels; and from my experience I feel perfectly sure in the results of testing samples, taken from every tenth barrel in any cargo or delivery.

W. R. Hutton, M. Am. Soc. C. E.—The difficulty with the cements used at the Naval Observatory was probably due, in a great part, to the "small margin of profits" to the contractors, as mentioned by Mr. Grant. There should be no difficulty in obtaining either Portland or Rosendale cements which would exceed the very moderate requirements of the specifications. Although the Portlands are deteriorated by great age, yet a certain period of time must elapse between their manufacture and use, and there must be a certain exposure to air to slack such free lime as they may contain. The domestic cements, on the contrary, should be used while fresh. The very low results, given in the paper, of the tests of Rosendale cements are remarkable. As a rule, it is very uniform in quality, and gives good results in the testing machine.

The Potomac cements have been in use since 1830 upon the Chesapeake and Ohio Canal, the Baltimore and Ohio Railroad, and local works. Formerly they were of uncertain and variable character, depending largely upon the care used in the selection of the stone and its manufacture. During the last twelve or fifteen years they have come into vogue in Washington, and have there a good reputation. Some of the layers give a remarkably quick-setting cement, equal in that respect to the Vassy, and like it, requiring to be mixed by the trowelful, and used almost within the minute. But the uses of such a cement are few. Other layers are of a less active set, and give very good results when not overloaded with sand. For important work along the Potomac it has been used with one to one and a half parts of sand. In its original estimates for the Chesapeake and Ohio Canal, in 1826, the Board of Internal Improvement estimated for the use of "water lime" to be brought from New York at a cost of $1.38 per bushel, delivered on the work. It was

to be used only below water-line in the tunnel, and in the bottom and facework of the locks, the remainder of the work to be built with common lime mortar.

The admixture of common lime to prolong the time of setting cannot be adopted without some loss of strength, although for most purposes good work may be obtained with the combination, and with some economy in cost. On the other hand, the addition of a small proportion of cement to lime mortar increases greatly its strength and hardening properties. In the facework of Dam No. 5, of the Chesapeake and Ohio Canal, Rosendale cement was mixed with that from Round Top (Potomac), to delay the setting, and with good results.

No doubt, the "personal equation" enters largely into the results of tests of cement, chiefly as regards the thoroughness of the manipulation and the degree of compression applied in packing it in the mould. This latter condition is particularly well known to the agents of the cement companies, and perhaps accounts for the offer by one of them to guarantee results if tests were made in New York. Uniformity of results is obtained by the use of what may be called the German method, referred to in the paper by Mr. S. Bent Russell, and this may be useful, in the comparison of different cements; but the treatment is so radically different from that which the cements get in actual practice that it is of no use in determining the practical value of the material. For that matter the usual tests for tensile strength give only a collateral indication of the value of the cement. What we need is adhesiveness and resistance to compression. So the one-day test is useful to indicate the age and condition of the cement, uniformity in a given delivery, or in the output from a given mill; but low one-day tests are not incompatible with very good results after one or several weeks.

Arson (Construction des gazométres) notes that those Portland cements which contain the least free lime are the most impermeable to water. The lime in time dissolves, leaving the cement porous. They also set more slowly and give the stronger mortar. His practice with the Portlands is to mix them, three parts sand to one of cement, with an excess of water, and let them stand on the mortar board from one to four hours, depending upon the age of the cement. The cement rejects the surplus water, which drains off, and the mortar gradually stiffens; when it has become pasty it should be used. The walls of gasholders are built with this mortar, but to render them water-tight they are plastered on the inside with Vassy cement, mixed with equal parts of sand. The cement is tested for tensile strength and for impermeability. It is found that mortars which are kept in the air are more permeable than those set in water. That a troweled surface is necessary—water under pressure, of two to three atmospheres, being applied to the back of a disk penetrated readily as far as the troweled skin, and was there arrested. If well troweled and the connections well made, the mortar should be

impermeable under 40 feet head of water. Care must be taken, however, to prevent a pressure from the outside of the wall, before the mortar has set.

The method of making grout described by Mr. Grant is certainly unique. Although the use of grout is now justly proscribed, it was formerly a usual method of building heavy masonry. The specifications of the Erie Canal provided that the joints should be filled with grout. On the Chesapeake and Ohio Canal its use was general, as upon the Baltimore and Ohio Railway. Dressed stones were bedded in mortar; rubble was laid dry, and all was grouted full. There are cases where its use cannot be avoided, as sometimes in the repair of old masonry; it should be forced in under pressure, as was done in the repair of the new (New York) Aqueduct, and around Mr. Greathead's City and South London Railway—in the one case by pumping, in the other by the pressure of air. A better method of filling joints than with grout is to work the mortar in by means of a "sword," a thin blade of steel, preferably serrated. All the ringstones of the Pont Ste. Marie in Paris were set in place dry with spacing strips in the joints, and when all were in place the joints were filled with mortar, not grout, by means of a sword or fiche. The arch stones of Cabin John Bridge of the Washington Aqueduct were laid on spacing wedges and filled with grout.

To recall the old experiments on this point, Rivot and Chatoney made a concrete block by pouring a grout of Portland cement (1 cement 0.25 water) under a head of 17 feet, into a closed box filled with broken stone, and with satisfactory results both as to strength and the complete filling of the voids. Vicat thereupon filled tubes with mortar of ordinary consistency and others with grout, using different proportions of water, 50 and 100 per cent. He found upon testing that the grout was much weaker than the mortar, and even that the material in the top of the tube was less hard than that in the bottom. As a comparison this is not conclusive. Rivot and Chatoney used but 25 per cent. of water, and applied the grout under considerable head. Although experiments show those mortars to be the stronger which are made with the least proportion of water, yet in actual work it is better to have the mortar rather soft than stiff. Better and more solid work is made with it, and its adhesion is greater.

Boehme's experiments indicate that the resistance of mortars of Portland cements to compression increases for from seven to twenty-eight days, more rapidly than its tensile strength; at twenty-eight days it is about nine times as strong. (The Prussian rule is ten times.) The tensile strength of his specimens (3 to 1) at twenty-eight days was 293 pounds per square inch, which is a little less than half that of the pure cements at the same age.

Mr. Grant's experiments of mixing clay with the mortar is hardly conclusive as to the admission of the impurities usually found in sand.

These consist most frequently, not of clay, but of loam, mica and organic matters. The strength and impermeability of concrete depend largely upon its being properly and sufficiently rammed. The breaking of the briquette in the testing machine at the point of contact of the clip is remedied by enlarging the surface of contact of the clip or by placing a bit of leather between the surfaces.

A. P. BOLLER, M. Am. Soc. C. E.—The following tests upon 12-inch cubes of concrete were made to determine the strength of the concrete used in the monolithic foundations built for the 155th Street viaduct, New York City. This concrete had been made with great care, and proportioned of one part Portland cement to two of sand, and four of 1-inch broken stone. The cement used was the well known Alsen brand, showing an average tensile briquette strength of 450 pounds in seven days. The batches were mixed quite dry, the successive layers of concrete just flushing moisture to the surface, under ramming with 35 pound metal rammers.

The tests were made October 5th, 1891, on the 1 200-ton horizontal machine of the Phœnix Bridge Works, the compression faces between which the blocks were broken having a ball-bearing attachment to the ram and head block. All the blocks with the exception of No. 6 were broken at right angles to the planes of ramming, and crushing surfaces were smoothed and made true with plaster of Paris. In all cases failure was accompanied with two resulting pyramids, the larger one of which was always the lower part of the specimens as rammed in the box forming the cubes. Specimen No. 6 had a piece about 3 inches thick split off in the plane in which it was rammed, the remaining thickness of 9 inches being crushed in the direction of the plane, instead of at right angles as above. This specimen had been fractured in shipment and was accidentally broken, although, like the other specimens, it had been shipped to Phœnexville in a wooden box made from 2-inch plank. It might possibly have been broken in nailing up the plank around it.

Experiment No. 1, made October 4th, 1890. The block was one year one day old, mixed from cement one part, sand two, and of 1-inch stone four parts. It was taken from the platform as mixed for the work, and having just enough water to show moisture on the surface when well rammed; weight of the block at the time of test 153½ pounds; crushed at 2 030 pounds per square inch, or 146 tons. The bottom pyramid was 8 inches high, with 10 by 11 inch base. The upper pyramid was destroyed in removing from the machine, to which it adhered through the plaster. The fractures were clean and sharp, many through the broken stone (Tompkins' Cove limestone), and the surfaces of the cone not friable.

Experiment No. 2. A block made from the same batch as No. 1, and more water added, so that it could not well be rammed, and would flow if the box were tipped over; weight at the time of the test, 152 pounds; crushed at 1 591 pounds per square inch, or 114½ tons. The bottom

pyramid was about the same size as that of No. 1. The edges of the pyramid were well defined and the surfaces sandy and friable.

Experiment No. 3, made October 22d, 1890. Block eleven months fourteen days old. Taken from the platform as mixed for the work as for No. 1, with just enough water to flush the surface when rammed; weight of the block at the time of the test 155 pounds; crushed at 1 636 pounds per square inch, or 118 tons. In this specimen, while the bottom surface was smooth the top surface was irregular, the box not having been properly filled, which may account for the great difference in strength from No. 1, where the crushing surfaces were in close contact with the machine, enabling the pressure to be at once uniformly distributed, while the irregular top surface of No. 2 brought the pressure at irregular points, save aid in the distribution by the plaster of Paris. The larger pyramid was 6 inches high, with a base having two sides 9½ and 10½ inches, and two sides 5½ and 6½ inches. The smaller and upper pyramid was approximately conical, with a base 5 inches diameter, and height of 4 inches. The fractures were clean and sharp.

Experiment No. 4, same as No. 3, with water added, so that the mixture could be rammed with difficulty, and would flow only slightly if the box were tipped over. The age at the time of the test was eleven months fourteen days, and the weight 154 pounds. It crushed at 1 680 pounds per square inch, or 121 tons. The bottom pyramid was 5½ inches high with a base 10 inches square. The fracture was not well defined, and the surface was friable and sandy. The upper pyramid crumbled as before in taking it from the machine.

Experiment No. 5, made October 22d, 1890. Block eleven months fourteen days old, with a weight of 117½ pounds. The mixture was: cement one, sand five, and no stone, and it was mixed very wet, so that water came freely to the surface when it was slightly rammed. This crushed at 1 015 pounds per square inch, or 72¾ tons. About 1½ inches at one edge of the block had been broken off, probably in its removal from the mould box. The surface was quite rough and required a thick coat of plaster to bring it true. The resultant bottom pyramid was 7 inches high and as near as may be 11 inches square. The upper pyramid was about 2 inches high with an elliptical base of 6 by 9 inches and a fracture sandy and friable.

Experiment No. 6, same as No. 5, with just enough water to show moisture when well rammed; weight, 127 pounds. This block was split slightly concave, as before noted, into two pieces 3 and 9 inches thick respectively. The experiment was made on the 9-inch piece in the direction of the layers, or perpendicular to the plane of ramming, and the block crushed at 1 072 pounds per square inch, or at the rate of 77 tons per cubic foot. The fracture was sandy and friable. The specimen split up as if it were under pressure and left no pyramids whatever.

Experiment No. 7, made November 6th, 1890. Block eleven months old; weight 147½ pounds, cement one, sand two, 1-inch stone five parts, mixed with just enough water to show moisture when well rammed. This crushed at 1 370 pounds per square inch, or 98½ tons per cubic foot. It did not break in regular pyramids; the lower piece was of irregular shape 7½ inches high, and the base about 11 inches square. The fracture was clean and sharp, and the surface not friable. The small or upper piece was not preserved or noted.

Experiment No. 8, same as No. 7, with more water added, so that it came freely to the surface when slightly rammed; age of the block 11 months; weight, 154½ pounds. It crushed at 1 883 pounds per square inch, or 136 tons per cubic foot. Two pyramids remained, the upper 5 inches high and with a semi-circular base 11 x 9 inches, and the lower 7 inches high, with a rectangular base 11 x 11 inches. The fracture was fairly sharp and the surfaces friable.

In the above experiments, the mould boxes were well soaked before concrete was put into them, and the crushing record noted from gauge readings, no allowance being made for the friction of the machine—an undetermined quantity. Briquette records of the cement, taken from the barrels from which the blocks were made, showed the following:

| No. of Experiment. | Neat. | | | Mortar, 1 Sand, 1 Cement. | | Mortar, 3 Sand, 1 Cement. | | Mortar, 5 Sand, 1 Cement. | |
|---|---|---|---|---|---|---|---|---|---|
| | 7 Days. | 3 Months. | 1 Year. | 4 Months. | 1 Year. | 4 Months. | | 4 Months. | 1 Year. |
| Experiments 1 and 2 | 399 | 526 | 728 | 415 | 715 | 186 | ..... | ..... | ..... |
| Experiments 3 and 4 | 540 | 654 | 692 | ..... | ..... | ..... | ..... | ..... | ..... |
| Experiments 5 and 6 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 152 | 189 |

Cement 98½ per cent., fine, 2 500 mesh sieve, briquette mixed with 20 per cent. water and left one day in air.

William H. Grant, M. Am. Soc. C. E.—The general tenor of this discussion strengthens the view which was the origin of my paper—that of showing the necessity of establishing more definite rules in the treatment of cements and mortars. It is quite satisfactory in that regard, and I make my acknowledgments for the commendatory remarks. The dissenting portions of the discussion require further attention.

Mr. J. Foster Crowell speaks of the tests at the Observatory as rigorous, and says a contractor cannot be reasonably expected to comply with them.

Mr. Arthur S. C. Wurtele thinks the tests were unreasonable. He also speaks, in the same connection, of "a curious and unjustifiable difference made in prescribing a lower test for Potomac cement than for

Rosendale." A little care in reading my paper would have shown that this latter remark did not apply to the Observatory, but to tests for municipal work in the City of Washington. As to the tests for the Observatory work which I have described, I took some pains to compare them with the requirements on other public works, with the tests which manufacturers guarantee for their brands, and the tests which many trials by experts show that cements, both foreign and domestic, easily bear; and I cannot, therefore, think that they were unreasonable. That a good deal of cement which was brought to the work proved of inferior quality is not to be taken, as most engineers, I think, will admit, as showing that the prescribed tests were too high.

Mr. Crowell thinks that if specifications covered the details of mixing (and tests) we would get better work, etc. I agree with him that it would be desirable to specify clearly the requirements and tests for cement in all cases, in order to avoid differences about them with contractors and dealers. This reply to Mr. Crowell may be briefly taken to cover Mr. Wurtele's objection to the cement tests. My tests were by no means so few as he thinks. I thought I had amplified the subject quite fully in my paper.

It seems to me he lays undue stress upon the circumstances which I mentioned of modifying the tests of domestic cements when only a small amount of work on top of the Observatory walls remained unfinished. I explained why, at this point, the Navy Department authorized the relaxing of the tests. If it was an extremely low requirement, but little harm could be done under the circumstances, and it was by no means an admission that the previous tests had been too high. In fact, a fair comparison of the tests for domestic cement (which was by far the largest in quantity used) with those required on other works, will show that they were below rather than above a usual and justifiable standard. As most of the members who participated in the discussion have passed over these points, I infer that they did not regard them as excessive.

Mr. Wurtele objects, quite properly, to any adulteration of sand. I mentioned an experiment I made with sand and clay intermixed, which showed an unexpected result, and I was inclined to attribute it to accident, suggesting that more experiments were desirable. I inferred from it, perhaps erroneously, that good sand might be tolerated when not containing more than 10 per cent. of ordinary impurities. In my experience purer sand than this is rarely found. Is it really important to incur the expense of washing such sand?

My remarks as to the use of grout were objected to by Mr. Wurtele. He says that his experience is that masonry, properly grouted, gives better results than that without the use of grout. We all know that grout is simply thinly diluted mortar, and it is a well established fact that mortar loses its vitality in proportion to the excess of water used in it; a further difficulty arises in its use, that of the sand and cement separating

from the water and gravitating to the bottom, or stopping short of the point it is intended to reach when used in any considerable quantity. I had some experience in the use of it on the New York State works, where it was quite a general practice, but have never been convinced that any work was better for it than if good mortar were substituted in its place. I must, therefore, leave the remark I made about it without further qualification.

It does not seem necessary on my part to extend this discussion, and I conclude by only adding that the interest manifested by members on the subject of my paper is regarded as a favorable omen that the suggestions made, and which have been especially so clearly enforced by Mr. Whittemore and Mr. Maclay, may receive the attention of the Society at an early day.

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TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

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# NEAT TESTS vs. SAND TESTS FOR PORTLAND CEMENT.

By S. BENT RUSSELL, M. Am. Soc. C. E.

WITH DISCUSSION.

The matter which I have to present will be found in the attached table and diagram. A few lines will explain their meaning and show how the data were obtained. The cement tests, from which the table was constructed, were all made recently in the laboratory of the St. Louis Water Works Extension. They were made not for the purpose of comparing the methods of testing, but for the purpose of comparing the tensile strength and value of twelve different brands of cement. In order to make a fair comparison it was decided to test each cement in three different ways.

First, forty briquettes of each brand were mixed on the jig. In this test enough cement for one briquette is weighed out into a brass cup, the proper amount of water is poured in, a tight-fitting cover put on, and two of these cups are violently shaken by a special machine called the jig.* When thoroughly mixed the mortar is removed from the cup and pressed into the mould by hand.

* Plates LVIII, LIX, LX and LXI show general and part detail plans of a jig. It is driven by a small power at the rate of about six hundred revolutions per minute. One minute is usually allowed for mixing a pair of briquettes.

Forty briquettes of each brand were then mixed by hand in the usual manner with a palette knife on a mixing table. In both of the above methods of test the cement was used without sand, and such proportion of water was used as would give a standard consistency of mortar. This consistency was such that when ready for the mould, the mortar could readily be formed into a ball about 1 inch in diameter with the fingers, and rolled in the palms without breaking. No more water was allowed than was necessary to produce this consistency, and this result would only be reached after about three minutes hard and skillful working with the palette knife for each briquette. In both hand-made and sand tests each briquette was made independently. The proportion of water for both hand-mixed and jigged briquettes was different for different brands. From 20 to 23 per cent. of the weight of the cement was taken.

Lastly, forty briquettes of each brand were mixed with sand. The sand was thoroughly dried and sifted between the No. 20 and No. 30 sieves, and was of superior quality; 44 grammes of cement and 132 grammes of sand were mixed in a basin with from 12 to 15 cubic centimeters of water, depending upon the brand. That proportion of water which would give the strongest briquette when taken from the mould was used. The mixed materials were then compacted into the mould with a trip hammer. After one hundred and fifty blows the briquette was removed from the mould. In all cases the moulds were of the form recommended by the Committee of the American Society of Civil Engineers. All briquettes after mixing were kept in air for twenty-four hours and then immersed in water.

We had then forty briquettes of each kind immersed. Ten of each kind were broken after six days in water; ten more after thirteen days; ten more after twenty days, and the last ten after twenty-seven days in water. All neat briquettes were broken on a Riehle cement-testing machine, using an articulated, "parallel motion clip." All sand briquettes were broken on a Fairbanks machine, using the American Society clip.

The above-mentioned mechanical mixer or jig, the trip-hammer, and the parallel motion clip are described in an illustrated article in the *Engineering News* of January 3, 1891. The trip hammer is of the kind used in Germany for cement testing, and the sand briquettes were gauged in the German style (this is indicated in the table by the letters D. H.), with the exception that the American form of mould was used.

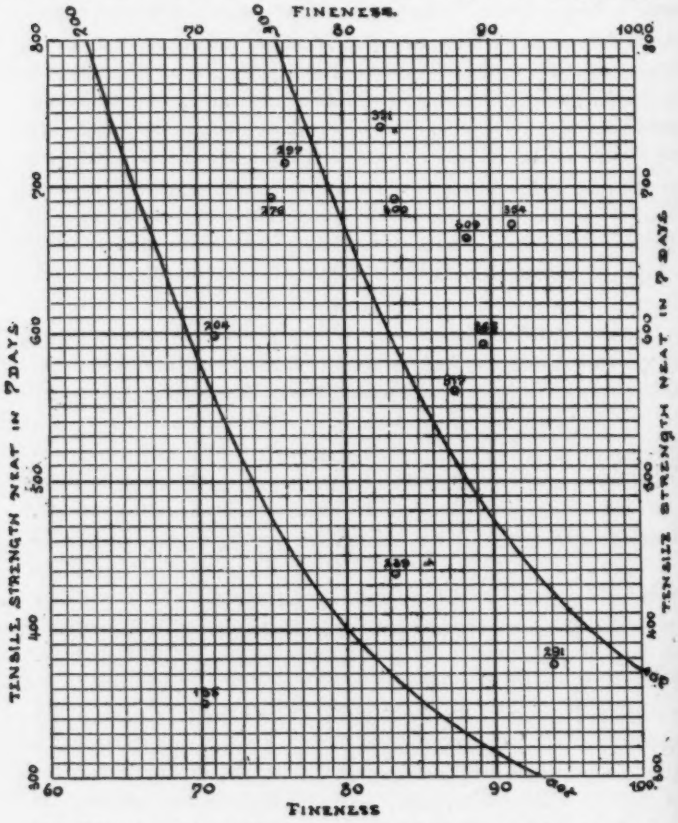
All of the tests were made by men of experience and skill in handling the apparatus and cement, and I am satisfied that each method had fair treatment. Of the twelve brands tested, five were German, two were English, three were American, one was Belgian and one was a German slag cement; all were Portland. After the tests were made the writer took advantage of the opportunity to compare the three ways of testing by their results.

One of the first requisites of a method of testing is uniform results with uniform material. To be thoroughly satisfactory the results should depend on the material only, and should, to a certain degree, be independent of persons, places, and seasons. To test a method by this standard would, however, take much time and study, and, moreover, concerted action by a number of experimenters. A good preliminary test of a new method can be made by observing the variation in the results of a given number of tests made at the same time with uniform material. In this case we have forty-eight groups of ten tests each to compare with forty-eight similar groups tested by another method. Taking the difference between the highest tensile breaking strength and the lowest in the group of ten tests we have the total variation for the group. Dividing this by the average of the ten tests, and we have the per cent. of variation for the group. With brand *A*, for example, we have in the first group of jig tests the highest test 728 pounds, the lowest 664 pounds, per square inch, making a variation of 64 pounds. The average of the ten tests was 691.2 pounds, so that we have a variation of 9 per cent. for the group.

Each number in columns 3, 4 and 5 of the table shows the per cent. of variation for a group of ten tests. A glance over these columns shows the comparative uniformity of the three methods. The forty-eight groups of briquettes mixed on the jig show an average variation of 14.7 per cent., and the maximum variation for one group is 33 per cent. The hand-mixed briquettes show an average variation of 22.5 per cent. and a maximum of 56 per cent., while the sand briquettes show an average of 27.3, and a maximum of 80 per cent. variation. We might say that the variations by the three methods are in the relation of 2, 3 and 4. This would indicate that the jig test is twice as reliable as the sand test, and 50 per cent. more reliable than the neat test by hand. It is proper to note that three sand briquettes of brand *K* broke in handling. These were not included in the averaging. No

other tests were thrown out. Brand *L* showed a tensile strength of 940 pounds per square inch in twenty-eight days by the jig test. This was the highest average of ten tests in the series. Ten sand briquettes of brand *E*, fourteen days old, showed an average breaking strength of 312 pounds per square inch, the best group of sand tests in the series.

DIAGRAM, showing the relation between the strength of cements after seven days and their ultimate strength for different degrees of fine grinding.




The diagram above indicates to what extent we may trust a seven-day neat test combined with a sifting test to show the value of the

cement when used in mortar. After three months' time a mortar may be said to have practically reached its working strength. Ten sand briquettes (1 to 3 by weight) of each of the twelve brands were broken when ninety days old. Each cement was plotted on the diagram, using its neat tensile strength in seven days when mixed on the jig, and its fineness on a No. 100 standard sieve as co-ordinates. The location of a point shows the strength in seven days of a certain brand, also its fineness. The figures written at the point so found show the average of the ten ninety-day tests of the sample mixed with three parts of sand to one of cement. For example, brand *C* is 88.6 per cent. fine, and has a neat strength in seven days of 665 pounds per square inch. With sand it shows an average strength of 309 pounds in three months. In the diagram the best cements are found grouped together in the upper right hand corner above the line marked 300, while the poorest cement is

PER CENT. VARIATION IN A GROUP OF TEN TESTS FOR TENSILE STRENGTH.

| Brand. | Days old. | 3 Neat. Jig. | 4 Neat. Hand. | 5 Sand. D. H. | Brand. | 3 Neat. Jig. | 4 Neat. Hand. | 5 Sand. D. H. |
|---|---|---|---|---|---|---|---|---|
| *A* | 7 | 09 | 12 | 21 | *G* | 25 | 31 | 44 |
| | 14 | 09 | 17 | 60 | | 11 | 35 | 22 |
| | 21 | 14 | 17 | 17 | | 15 | 15 | 25 |
| | 28 | 30 | 08 | 32 | | 27 | 12 | 14 |
| *B* | 7 | 09 | 18 | 20 | *H* | 10 | 56 | 31 |
| | 14 | 10 | 25 | 73 | | 7 | 36 | 30 |
| | 21 | 10 | 20 | 21 | | 20 | 36 | 19 |
| | 28 | 16 | 26 | 31 | | 16 | 20 | 20 |
| *C* | 7 | 11 | 13 | 32 | *I* | 18 | 16 | 19 |
| | 14 | 10 | 16 | 18 | | 15 | 27 | 29 |
| | 21 | 10 | 17 | 18 | | 12 | 39 | 35 |
| | 28 | 27 | 08 | 10 | | 33 | 36 | 28 |
| *D* | 7 | 10 | 14 | 14 | *J* | 17 | 37 | 22 |
| | 14 | 10 | 33 | 24 | | 09 | 20 | 14 |
| | 21 | 9 | 18 | 11 | | 24 | 30 | 32 |
| | 28 | 26 | 20 | 27 | | 14 | 14 | 25 |
| *E* | 7 | 20 | 56 | 24 | *K* | 22 | 17 | 80 |
| | 14 | 10 | 20 | 22 | | 21 | 22 | 23 |
| | 21 | 13 | 14 | 26 | | 12 | 17 | 34 |
| | 28 | 17 | 25 | 17 | | 11 | 19 | 34 |
| *F* | 7 | 09 | 09 | 20 | *L* | 09 | 17 | 25 |
| | 14 | 12 | 12 | 35 | | 18 | 14 | 36 |
| | 21 | 09 | 17 | 11 | | 10 | 36 | 33 |
| | 28 | 22 | 24 | 24 | | 11 | 09 | 32 |
| Average | | | | | | 14.7 | 22.5 | 27.3 |
| Maximum | | | | | | 33 | 56 | 80 |
| Minimum | | | | | | 7 | 8 | 10 |

found in the lower left hand corner below the line marked 200. As is generally conceded, the fineness plays an important part. The plotted points may be considered as points on a sloping surface, the figures showing the elevations. The lines marked 200 and 300 would then represent contour lines.

One of the disadvantages of the sand test that may be mentioned is that even when a standard sand is used, the heaviest cements do not stand a fair chance when the proportions are by weight. On a work the proportions are usually by volume. A standard sand for testing is often not to be conveniently obtained, and different sands have different specific gravities, so that on the whole the sand test by weight does not show the comparative value of cements as used in a work. Moreover, in diluting our cement with sand we practically reduce the size of our test. Who would advocate reducing the size of our briquette?

## DISCUSSION.

D. J. Whittemore, Past-President Am. Soc. C. E.—In support of some of the deductions made by Mr. Russell, it may be that calculations based on extreme variations in tests of one group from those of another of a different or of a same brand of cement may be satisfactory, yet knowing that some cements are quite uniform as to quality and that others are not so, it appears to me that more conclusive evidence could be deduced from tests of one uniform quality and brand, in an attempt to judge of the merits of the various modes of gauging mortars. To secure this uniformity I have in many cases found it necessary to remix the cement in a dry state, and this can easily be accomplished by its repeated sifting into a funnel, whereby particles of cement from throughout the area of the sieve are brought together at the outlet of the funnel, thus insuring pretty thorough mixing. With cements thus made uniform, the method generally adopted by me in comparing different methods of gauging and testing has been, to ascertain the average variation of all tests from the mean of the individual tests of a group, and not that of the single tests of a group showing highest and lowest results.

In my paper in *Transactions*, Am. Soc. C. E., Vol. IX, page 329, upon Tensile Tests of Cements and an Appliance for more Accurate Determinations, it will be observed that I used the method suggested. Mr. Russell's testimony shows that the jig gauging is superior to that done by hand; and this fact, if it is a fact, leads me to again suggest the propriety of appointing a committee of our Society to consider and advise

PLATE LVIII
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXV. Nº 499.
RUSSELL ON CEMENTS, &c.

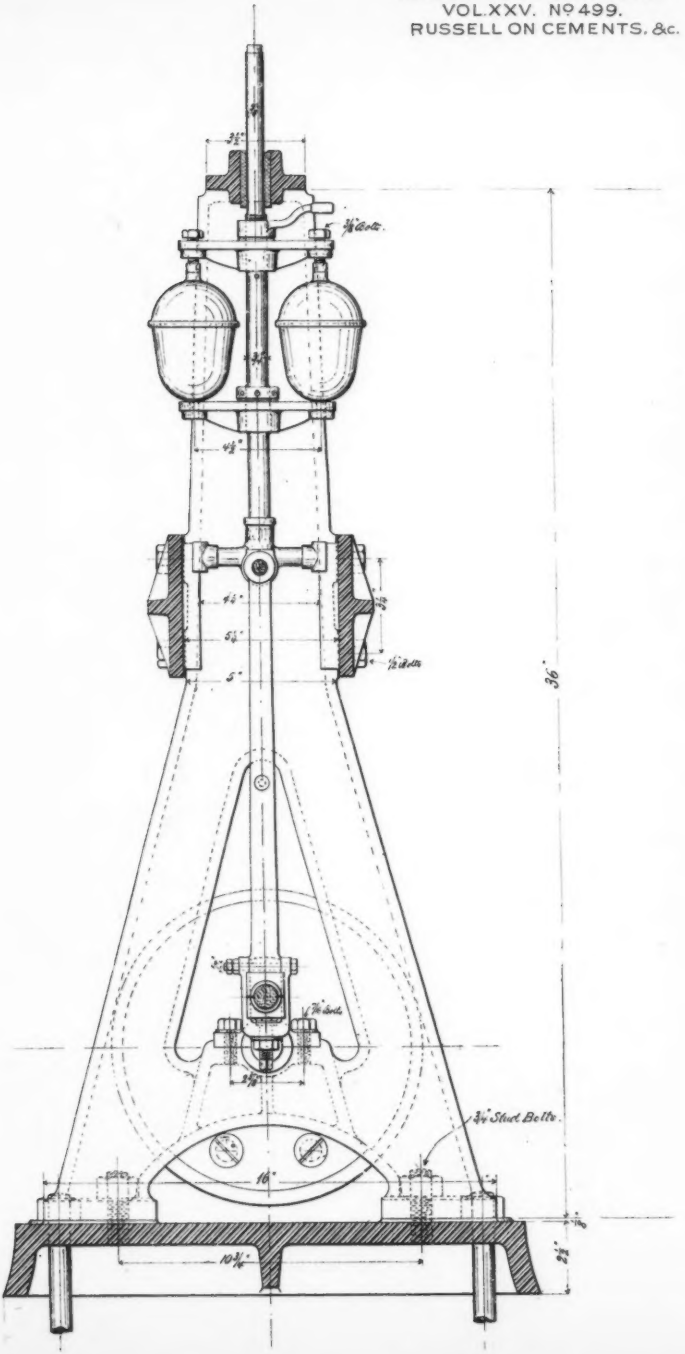


PLATE LIX
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXV. Nº 499.
RUSSELL ON CEMENTS, &c.

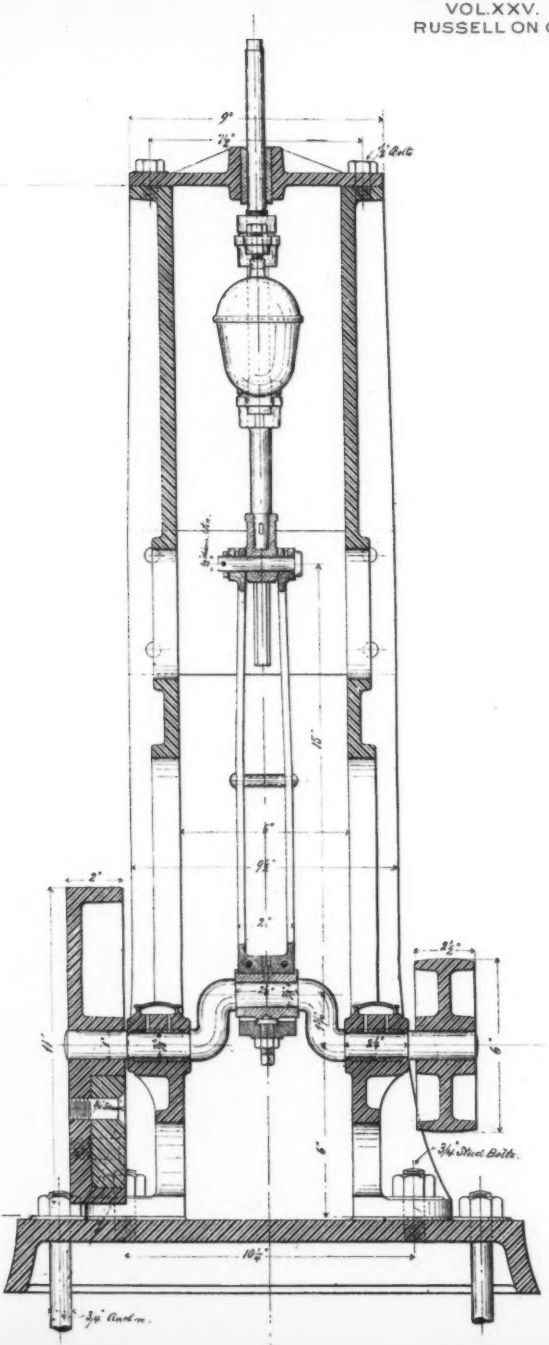


PLATE LX.
TRANS. AM. SOC. C. E.
VOL. XXV, No. 499.
RUSSELL ON NEAT TESTS vs. SAND TESTS
OF CEMENTS.

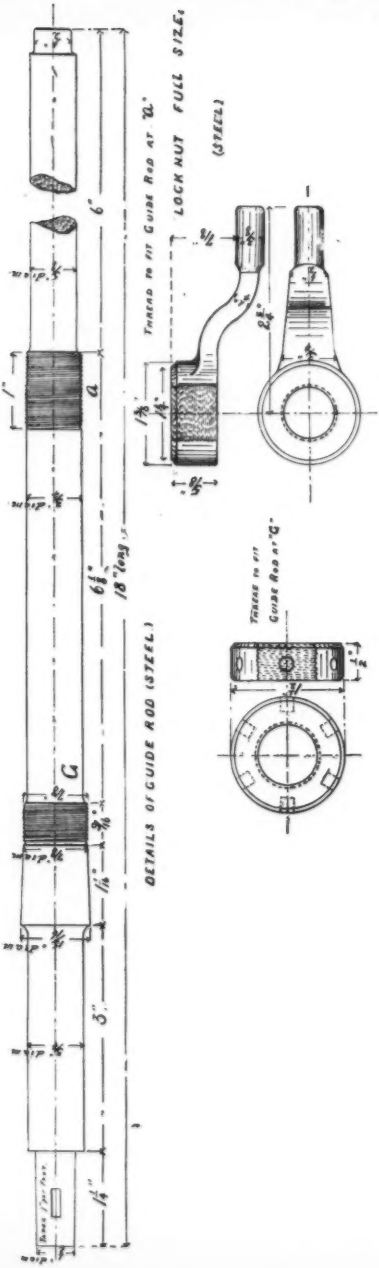


PLATE LXI.
TRANS. AM. SOC. C. E.
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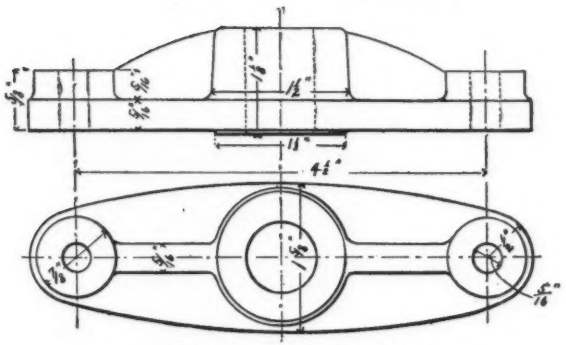
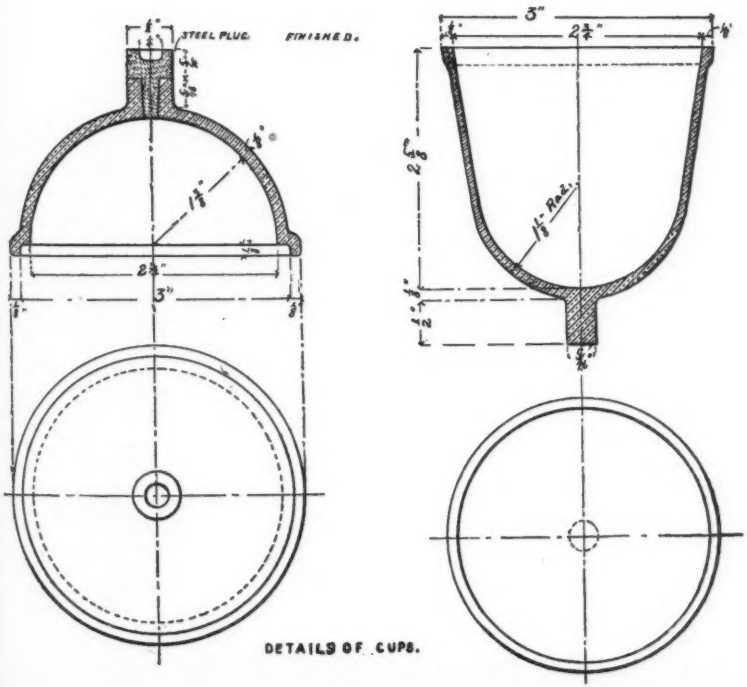
RUSSELL ON NEAT TESTS vs. SAND TESTS
OF CEMENTS.




DETAILS OF CUP SUPPORTS.




DETAILS OF CUPS.

additions to the rules heretofore formulated by the former Committee on Cement Tests. No one will dispute that those rules have been of great value to our members, but if they can be made more complete and definite, it is the evident duty of our members to make them so. It is my belief that the rules promulgated by our Society were at the time they were issued, and are now, sufficient to guide an intelligent experimenter towards the desired end; yet all experimenters are not remarkably intelligent, and it is to meet this emergency that I urge the adoption of more complete and definite rules, and the employment of some one or more of the numerous devices for fabricating briquettes that result in economy of labor and in securing uniformity.

It has been my lot to be interested in the manufacture of cements for many years, and, therefore, I have had more than usual opportunities to observe the work of novices in testing. It is not uncommon to find such whose first impressions of mortar for test purposes are, that it should have the consistency of a mud puddle. An instance of this character was recently brought to my notice: that of an engineer in an important city in Ohio, pretending to work under our rules, who used 42½ per cent. of water in gauging. I can understand how he blundered to the extent of say 12 per cent., but by what process of reasoning he tacked on the one-half per cent. is beyond my comprehension.

My experience has been that the manufacturers of cement have had but little reason to find fault with the work of the engineer who is expert in conducting tests, as they know that there is satisfactory foundation for any complaints he may make, but it is the work of the non-expert that gives them the greatest trouble, expense and discredit, and it is to meet such cases that I particularly urge a revision of our rules. Methods for better gauging and testing should be considered. Henry Faija, M. Inst. C. E., has devised a cement gauger now used by upwards of a hundred firms, corporations and persons in England, by which it is claimed that the cement can be reduced to the proper consistency as a mortar for forming briquettes, in considerably less time and with much less water than is possible by even the most expert hand gauging. He has also devised an apparatus for determining the soundness of cements in a few hours, which is based on the principle that moist heat accelerates the setting, and that if judiciously applied the indurating effects of several days under normal exposure of briquettes may be artificially given and determined in a few hours (Minutes of Proceedings, Inst. C. E., Vol. LXXV, pages 213-30).

Frederic Ransome, of London, has also devised a method of moulding briquettes in which the question of water to be used is entirely eliminated; simply by moulding the briquette with cement and any other admixture desired in a dry state, and allowing the same, while yet in the mould, to be submerged in the water. I understand that it is claimed that briquettes thus moulded show, when tested by groups, a variation from the mean of only about two and one-half per cent.

Our member, Charles D. Jameson, Professor of Engineering of the State University of Iowa, has devised a briquette making machine of which an illustrated description is given (in Plate LXII) by which two persons can fabricate six hundred samples per hour, and an examination of reported tests shows variations of about 12½ per cent. only in strength. All these appliances might well be considered, and the best recommended by a committee of the Society.

"The description of the machine is as follows: The main bulk of the machine is made up of the cylinder, *A*, which is flanged at the lower end, corresponding in shape and size to the upper part of the base seen in Fig. 5, and bolted to it by four bolts provided with fillers so as to separate the lower face of the cylinder and the upper face of the base exactly one inch. It is between these faces that the moulding plate, *L*, seen in Fig. 4, swings, the fillers on the bolts acting as stops. The cylinder is made up of two parts bolted together. The bore is of the shape and size of a briquette and may be seen in plan in Fig. 3. In this bore works a solid plunger of such a length as to cover the feeding hole, *M*, when at its lowest point, and connected to the lever, *B*, by the connecting rod, *C*. The fulcrum of *B* is supported by *D*. About the point, *E*, Figs. 3, 4 and 5, the plate, *L*, swings in such a way that when at either extreme one of the openings is directly beneath the cylinder, while the other is directly over the plunger, *F*, the top of which, when at its lowest point, is a little below the under face of the moulding plate. These plungers, *F F*, are of the shape of the opening in the moulding plate and are raised by the levers, *G G*, and are to force the briquettes from the mould. They are each provided with two guide pins, *K K*, which work in holes in the base plate. The levers, *G G*, are attached to the base plate by bolts seen in Figs. 3 and 5. Small pieces, *H H*, are riveted to the levers and pass under the plungers. It is by means of these that these plungers are lifted. At the outside of the cylinder is the hopper, *I*, seen only in Fig. 1, which communicates with the interior through the opening *M*, seen in section in Fig. 6.

"The method of operating is as follows: The lever, *B*, being raised so that the lower end of the piston or main plunger is above the hole in the side of the cylinder communicating with the hopper, cement or mortar is put in the hopper and pushed down into the cylinder. The moulding plate is pushed against one of the stops, so that one of the openings is beneath the bore of the cylinder. The long lever, *B*, is forced down, causing the plunger to force the cement into the opening in the moulding plate. After this, the moulding plate is swung against the other stop, cutting off the briquette, placing it over the plunger, *F*, throwing the other opening in the moulding plate directly beneath the cylinder. The lever, *G*, is lifted, raising the plunger, *F*, and forces the briquette out of the mould, after which it is removed. The plunger, *F*, is then pressed down, the main lever, *B*, pressed down, the moulding plate swung back to the first position, the other plunger lever, *G*, lifted, and another briquette is ready to be taken away, and so on. After making two or three briquettes, the main lever is lifted and more material put into the cylinder. The machine is best operated by two men, one to feed and operate the long lever, and the other to swing the moulding plate, remove the briquettes and lower the plungers, *F F*. The pressure on the briquette is about 175 pounds per square inch." *

* Copied from *The Transit* of December, 1890.

PLATE LXII
TRANS.AM.SOC.CIV.ENG'RS
VOL.XXV.Nº499.
WHITTEMORE ON
NEAT TESTS VS.SAND TESTS OF CEMENTS.

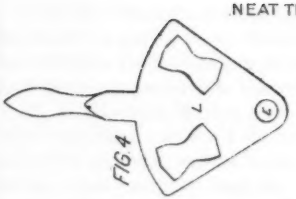


FIG 4

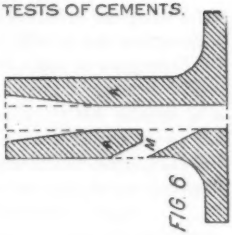


FIG 6

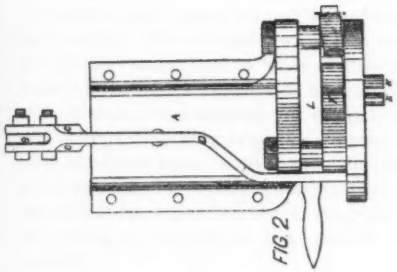


FIG 2

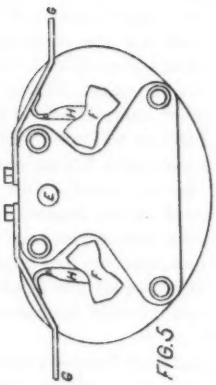


FIG 5

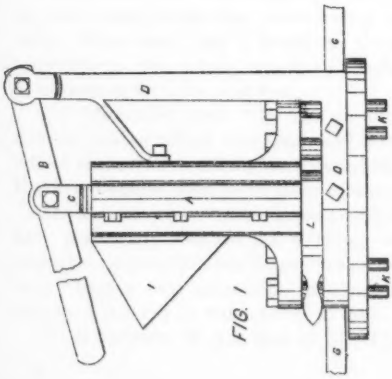


FIG. 1

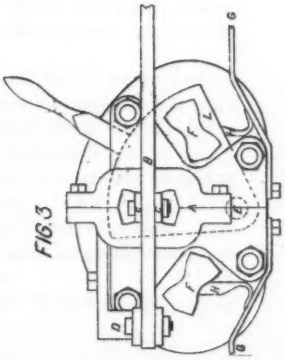


FIG 3

I beg Mr. Russell's pardon for wandering so far from the particular feature of his paper, in my discussion of it, and offer as my excuse that the subject is far reaching in its nature, and that what is suggested by me is certainly germane to the subject of cement tests in general.

W. W. MACLAY, M. Am. Soc. C. E.—The paper by Mr. Russell is a very interesting one, but I do not agree with his conclusions as to the reliability and comparative value of the three methods of testing experimented upon; namely, that the jig test is twice as reliable as the sand test, and 50 per cent. more reliable than the neat test by hand.

In the first place, it seems to me the comparison should have been confined to the neat test by hand with the neat test by machinery or jig, and to do this it would have been better to have taken the averages of the ten briquettes in each set in columns 3 and 4 of the table, instead of the percentage variation between the extreme breakings; then with the same material to have made up duplicate or triplicate sets, and have compared the resulting averages with one another. I think such a table would give one a better idea of the accuracy than could be obtained from each system. For example, while it is recognized in the German rules for testing cement that in cases of dispute machinery shall be resorted to, and Dr. Boehme's apparatus be used both for mixing and compacting the material in the moulds, yet in my experience with a person trained and skillful in making briquettes, I have obtained average results from re-tests of the same cement made by hand, both neat and mixed with sand, not differing from the original tests more than 2 to 5 per cent., and this not as the exception but as the rule. Such hand-mixing seems to me about as accurate as it is possible to make cement tests by any method.

After neat tests by hand and machinery had been prepared the sand tests with duplicate and triplicate sets could be made, and then the average results compared with each other, but not with the neat tests; for while the sand tests bear some relation to the neat tests, they do not vary in the same ratio, even when considering the element of fineness. The value of the sand test is based on the fact that it is a much nearer approach to the actual condition under which cement is used in construction than the neat test.

Dr. Michaelis says: "If the question were raised as to testing cement, neat or mixed with sand, and if it were acknowledged that only one of these two methods were permissible, then there was no doubt that the decision must be in favor of the sand mixture."

Mr. Russell says: "After three months' time a mortar may be said to have practically reached its working strength." From experiments carried on during the last fifteen years on many brands of cement, there occur only a few exceptions in which the sand briquettes have not increased steadily in strength up to three years.

W. R. HUTTON, M. Am. Soc. C. E.—Upon Mr. Russell's paper it may

be remarked, that the method of filling moulds with the trip hammer develops the very highest qualities of the cement and is deceptive if results are compared with those obtained in other ways. It is eminently a manufacturers' test. Pressure by means of weights applied according to some fixed standard would perhaps better replace the uncertain pressure of the trowel in the hands of the experimenter.

Would it be more fair to refer to the percentage of variation to the mean results instead of the opposite extreme?

S. BENT RUSSELL, M. Am. Soc. C. E.—In reply to questions that have been asked, I will attempt to describe a little more fully the method used in gauging the sand briquettes for the experiments.

Dr. Boehme's hammer machine consists of a trip hammer operated by a hand-crank, a mould, and a plunger which fits the mould. The trip hammer is provided with an automatic counting gear which stops the movement after 150 blows. The hammer strikes the plunger, which passes through an iron block which rests on the briquette mould and conforms to it in outline. In using this apparatus, the cement, sand and water are mixed in a hand-basin with a spoon until the mixture is apparently uniform. It is then of a mealy consistency. Sufficient of this mixture to form one briquette is then poured into the mould and plunger block, the plunger set on and the hammer started. The crank is turned as fast as the fall of the hammer will permit, which is somewhat deliberately, until it stops automatically. The plunger and cap are removed and the briquette is then shaved off with a knife and at once removed from the mould. If too much or too little water is used the briquettes will not come out well.

The letters D. H. in the table signify that the above-described method of gauging has been used, and are an abbreviation of "Dutch Hammer," which is the laboratory name of the Boehme machine.

When the jig was devised, the intention was to obtain a machine which would imitate as closely as possible the gauging done by hand. The mortar is mixed in the jig of about the same consistency as in the hands of a skilled experimenter, and the results obtained agree closely with those of the most skillful and painstaking hand mixing. The adoption of such mechanical methods seems to me to be a step in the right direction.

I am much pleased to hear from our Past-President, who was a member of the Society's committee on uniform tests of cement, that he is in favor of a revision of the committee's report, made nearly seven years ago. I am heartily in favor of such a revision, and have already advocated it elsewhere. After seven years' use we should be able to criticise the report intelligently. For myself, I should say that if there be faults in the report they are rather sins of omission than of commission.

AMERICAN SOCIETY OF CIVIL ENGINEERS.
INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

500.

(Vol. XXV.—September, 1891.)

# THE MARENT GULCH VIADUCT.

By GEORGE S. MORISON, M. Am. Soc. C. E.

The Portage Viaduct was built in the spring and early summer of 1875. The Marent Gulch Viaduct was built in the fall of 1884 and the following winter. The height of the iron work at the highest tower is practically the same for the two viaducts, and the length of the viaducts is also very nearly the same. The Portage Viaduct was built in the hurry of a pressing necessity, with little time to investigate relative economies or to prepare well considered plans. No such haste existed in the case of the Marent Gulch Viaduct, and the plans were carefully considered and worked out. The Marent Gulch Viaduct, therefore, represents ten years' advance in iron viaduct construction, besides such improvements as careful preparation always gives opportunity for.

The Marent Gulch Viaduct is in Montana, on the main line of the Northern Pacific Railroad, a little west of Missoula. Like the Portage Viaduct, it replaced a wooden viaduct already built on the same location, but unlike the Portage Viaduct, the replacement was made, not after destruction of the wooden viaduct by fire, but in anticipation of such destruction, which, in the dry climate of Montana, was considered a risk which the traffic of a transcontinental railroad should not be exposed to.

The wooden viaduct was built only two years before the iron viaduct. It was entirely of wood, without masonry foundations. It was built in alternate spans of 20 feet and 50 feet, two bents being braced together under the short spans, so as to form timber piers. The 50-foot spans were Howe trusses with wooden angle-blocks, which deflected so much that it was found necessary to reinforce them before the completion of the iron viaduct.*

The dimensions of the new viaduct were fixed in part by those of the old viaduct. The distance from center to center of piers in the new viaduct was made 140 feet, which brought the piers under the centers of the alternate long spans of the old wooden viaduct. The distance between the centers of the trusses, or the width of the piers at the top, was made 20 feet, this being the same as at Portage, but the object of adopting this width was to raise the new iron trusses without disturbing the old wooden ones (an object which the necessary renewal of the new trusses partially overcame), whereas the width of the Portage Viaduct was fixed with reference to substituting a double track superstructure for the original single track superstructure (which has never been done).

The general arrangement of the Marent Gulch Viaduct is shown on Plate LXIII. It consists of five spans, each 116 feet 8 inches long; of four towers, each measuring 23 feet 4 inches on top, and four girder spans of 30 feet each, making the total length of the entire structure from outside to outside of iron work 796 feet 8 inches. The total height from top of masonry to top of stringer is 201 feet 9 inches, this being at the high side of the two central towers. The viaduct is straight, but is built on a grade of 1.962 per cent.

### Substructure.

The substructure consists of two small abutments and twenty-four small piers. The details of these piers are given on Plate LXIV. They are generally founded upon rock, but in two instances they were founded on clay and gravel, the area of the foundations being increased; and in two other instances they were founded on piles driven in clay and gravel and reaching a hard material which probably was rock.

Two plans were prepared for these piers; one was for masonry piers,

* A historical description of the Marent Gulch Viaduct, including the timber structure, will be found in a paper by S. D. Mason, read before the Civil Engineers' Society of St. Paul, and printed in the Journal of the Association of Engineering Societies for April, 1889.

which was adopted; the other consisted of concrete piers inclosed in wrought-iron shells covered with cast-iron caps. The author's judgment was in favor of the concrete piers, as he believed they could be more cheaply constructed. General Adna Anderson, M. Am. Soc. C. E., who was at that time Chief Engineer on the Northern Pacific Railroad, however, preferred the masonry piers, which were therefore built. They were built of limestone from the quarries at Kasota and Mankato, Minnesota, the stone being carried more than 1 300 miles by railroad. The abutments are granite. Each small pier had a 2-inch anchor rod built into the masonry, extending from the concrete or bottom of the foundation to the top, thus tying the whole masonry together.

The quantities of material in the substructure are given in the following table:

| Pier or Abutment. | Excavation. | | Concrete. Cubic Yards. | Cut Stone Masonry. Cubic Yards. |
|---|---|---|---|---|
| | Rock. Cubic Yards. | Earth. Cubic Yards. | | |
| Earth Abutment | 36 | ..... | ..... | 23.12 |
| Pier A | 48 | ..... | ..... | 6.47 |
| B | 48 | ..... | 3.71 | 6.47 |
| C | 39 | ..... | 8.63 | 22.91 |
| D | 66 | ..... | ..... | 37.01 |
| E | 66 | 112 | 15.67 | 16.01 |
| F | 30 | 143 | 28.18 | 38.03 |
| G | 56 | 105 | 15.26 | 28.74 |
| H | 98 | 389 | 5.85 | 55.76 |
| I | 132 | 229 | ..... | 21.77 |
| J | 125 | 116 | 21.70 | 33.30 |
| K | 77 | 470 | 41.92 | 31.20 |
| L | ..... | 280 | 67.60 | 37.58 |
| M | ..... | 240 | 56.46 | 37.58 |
| N | ..... | 195 | 63.16 | 37.16 |
| O | ..... | 389 | 122.38 | 27.57 |
| P | 122 | 702 | 48.89 | 27.38 |
| Q | 93 | 165 | 31.48 | 60.53 |
| R | 241 | 30 | ..... | 51.78 |
| S | 58 | 124 | ..... | 32.82 |
| T | 119 | ..... | ..... | 10.17 |
| U | 18 | ..... | ..... | 14.57 |
| V | 15 | ..... | ..... | 13.15 |
| W | 18 | ..... | ..... | 5.93 |
| X | 18 | ..... | ..... | 5.93 |
| West Abutment | 122 | ..... | ..... | 40.39 |
| | 1 645 | 3 689 | 543.80 | 722.33 |

SUPERSTRUCTURE.

The superstructure comprises two high towers, two towers of medium height, four bents, five pin-connected deck spans and four plate girder spans. Except for the slight irregularity caused by the grade, the structure is perfectly symmetrical, an unusual thing in a viaduct of this class.

The towers were made of the same length on top as the panels in the spans between them, so that the floor system is entirely uniform over the trusses and the towers, the length of towers being 23 feet 4 inches. The towers are built with a batter of one in forty-eight in the direction of the bridge, which increased the length of the high towers at the base to 31 feet $2\frac{3}{16}$ inches, and with a side batter of one in six (the Portage batter is one in eight), which makes the width of the high towers at the base 83 feet $2\frac{1}{2}$ inches.

The strain diagrams of the towers are given on Plate LXV. They were calculated to resist four classes of strain:

*First.*—The live load brought on top of the tower.

*Second.*—The dead load brought on the top and also at intermediate points.

*Third.*—The wind pressure brought on the top and also at intermediate points.

*Fourth.*—The traction strain due to the pull of a locomotive or the resistance of brakes, all of which is applied at the top of the tower.

An examination of the diagram shows that with a maximum wind pressure and no live load—an inconceivable condition—a small tension may exist at the bottom of the tower on the windward side. It also appears that with a combination of all maximum conditions, tension may exist from the effects of traction at the same point in one leg only of the four legs of a tower; this is a very improbable supposition, and the existence of tension at only one of the four points of support could not endanger equilibrium.

The width of the towers at the base is so great that it became necessary to make some provision for expansion and contraction in the horizontal members. The arrangement adopted is shown on Plate LXVIII. On one side the foot of the post is bolted securely to the cast wall plate which is anchored to the masonry. On the other side the attachment is made through a rocker of cast-steel, which rocker permits of expansion and at the same time is able to resist some tension. The superstructure

is bolted rigidly to the tops of the towers, excepting at two points on towers *C* and *F*, where expansion rollers are provided, these rollers being of steel running on steel castings. The expansion, therefore, of the central span is taken up by the spring of the lofty towers which support it.

The full details of the towers are given on Plates LXV to LXXI inclusive.

It will be observed that each tower rests on four points only, the stiffening members (which in the Portage Viaduct rest on the old stone piers) being sustained by the diagonal bracing.

The spans consist of deck pin-connected trusses, the full details of which are given on Plates LXXII and LXXIII. It will be observed that there is a complete iron floor, the floor-beams resting on top of the cords and the stringers on top of the floor-beams, the stringers being continuous and uninterrupted. On these stringers is laid the wooden floor, the details of which appear on Plates LXVII and LXXII.

The actual weights of material in the superstructure are as follows:

| | Pounds. | Pounds. |
|---|---|---|
| Two high towers, *D* and *E*..... | 549 113 | |
| Two towers, *C* and *F*..... ..... | 276 804 | |
| Bents, *B* and *G*..... | 34 036 | |
| Bents, *A* and *H*..... | 8 398 | |
| Total towers and bents..... | | 868 351 |
| Five deck spans..... | 466 700* | |
| Floor system..... | 297 827 | |
| Total deck spans ..... | 764 527 | |
| Four plate girder spans..... | 40 161 | |
| Total spans and floor..... | | 804 688 |
| Total iron and steel..... | | 1 673 039 |

The superstructure was manufactured from designs prepared by the author, and except 160 eye-bars, was made by the Union Bridge Company at their Buffalo shop; the 160 eye-bars were made by the Passaic Rolling Mill Company at Paterson, N. J. The superstructure was inspected by

*In this table the weight of the eye-bars is taken at 141 660 pounds, which is the actual weight. The original estimate was 118 938 pounds, but the section of the bars was increased 20 per cent. beyond the original provisions, the first lot of bars furnished not meeting the requirements of the specifications.

Mr. George A. Lederle, Assistant Engineer, who, on the completion of the work at the shops, superintended the erection in the field. All work at the bridge site was done by the company's own men without a contract.

The stone piers were built and the towers erected before any change was made in the timber viaduct, the timber structure serving as a scaffold. The stone work was handled by derricks placed on the hillside, and the material was passed from one derrick to the other until set in its final position. The iron work was handled by a derrick car worked from the top of the bridge, and the sections lowered into place directly from the car. The derrick car had two booms (see Plate LXXIV), and the members were picked up by this car from a yard east of the bridge; the car was run out on the bridge with the two members swinging from it and balancing each other; the members were then lowered into position, none of the principal members being handled on push-cars or moved forward in any other position except when swinging from the derrick-car. In this way the towers were raised to the top.

The trusses would also have been raised without disturbing the timber work, except for the fact that the old Howe trusses had been supplemented by new trusses placed on the outside of them after the erection of the iron bridge had been determined upon and before it was completed; it was therefore necessary to move the timber trusses toward each other, so as to give room to raise the iron trusses. The material for the new iron trusses was handled in the same way as that for the towers, and erected on staging supported by the timber towers and by hangers from the wooden spans.

After all the new trusses were swung the new floor system was put on, one new span being handled at a time. This change included the removal of the two timber spans, the placing of six iron floor-beams, of seven spans of iron stringers, and of the ties of the timber floor, all of which was accomplished in from six to seven hours and between the passage of trains. After the completion of the new iron structure, it was in turn used as a staging to take down the timber structure; this was handled with the same derrick-car, the timber being raised to the floor, loaded on a flat car and carried away for use elsewhere.

The work at the bridge site was not driven. Work was begun there about the first of September, 1884; the new iron structure was completed in April of the following year, and the wooden structure had been entirely removed a month later.

The cost of the structure was materially increased over what the cost of a similar structure in other parts of the country would have been, by three items: first, the fact that much of the work was done in the winter; second, the high rate of wages in Montana; third, the large amount of transportation.

The cost of the viaduct complete was as follows:

| | | | |
|---|---|---|---|
| Foundations | $21 664 59 | | |
| Masonry | 30 079 81 | | |
| | | | $51 744 40 |
| TOTAL PIERS. | | | |
| Iron work for towers and bents | $33 431 51 | | |
| Erection towers and bents | 15 756 93 | | |
| | | $49 188 44 | |
| TOTAL TOWERS AND BENTS. | | | |
| Iron work of spans and floor | $30 065 73 | | |
| Erection of " " | 6 528 21 | | |
| | | 36 593 94 | |
| | | | 85 782 38 |
| TOTAL IRON WORK. | | | |
| Timber floor and track | | | 4 923 49 |
| Painting | | | 1 826 74 |
| Engineering and incidentals | | | 9 085 15 |
| Total | | | $153 362 16 |

To this was added the charge for transportation on the line of the Northern Pacific Railroad, which made the entire cost of the structure $178 105 64. If we compare this cost with that of the Portage Viaduct, only the iron work, floor and painting should be included, these items aggregating $87 609 12. The structure itself, without the masonry foundations, could have been erected in the eastern part of the country for about $75 000.

The total area circumscribed by a polygon embraced between the top of the stringers and a broken line connecting the centers of the bridge seats on the several pieces of masonry is 95 735.52 square feet. The total area of a broken line embraced between a line forming the bottom of the stringers and the same broken line is 93 712.98 square feet. The iron work included within the larger polygon is 1 673 039 pounds, being 17.47 pounds per square foot, and within the smaller polygon is 1 461 879 pounds, being 15.59 pounds per square foot.

If we consider only the portion of the bridge where it is highest, the total area included in a quadrilateral the top of which is the top of the stringers, the bottom of which is a line connecting the centers of towers

*D* and *E* at the level of the top of the masonry, and the sides of which are the axes of the two respective towers, is 28 189 square feet; the weight of iron within this area is 421 026 pounds, or 14.93 pounds per square foot. If we take off the height of the stringers the area becomes 27 833 square feet and the weight 403 119 pounds, or 14.48 pounds per square foot. If we also take off the height of the floor-beams, the area becomes 27 367 square feet, the weight 373 658 pounds, and the weight per square foot 13.65 pounds. If we take off the floor-beams, but retain the stringers, which practically corresponds to the conditions at Portage, where the cross timber floor-beams rest on the cords, the area becomes 27 723 square feet, the weight 391 565 pounds, and the weight per square foot 14.12 pounds. These several figures are interesting for purposes of comparison.

The appearance of the structure is good, and if the author had occasion to build a bridge on the same location, he would make comparatively few changes, one of these changes being, perhaps, the substitution of a stiff riveted bracing for the adjustable bracings of the towers.

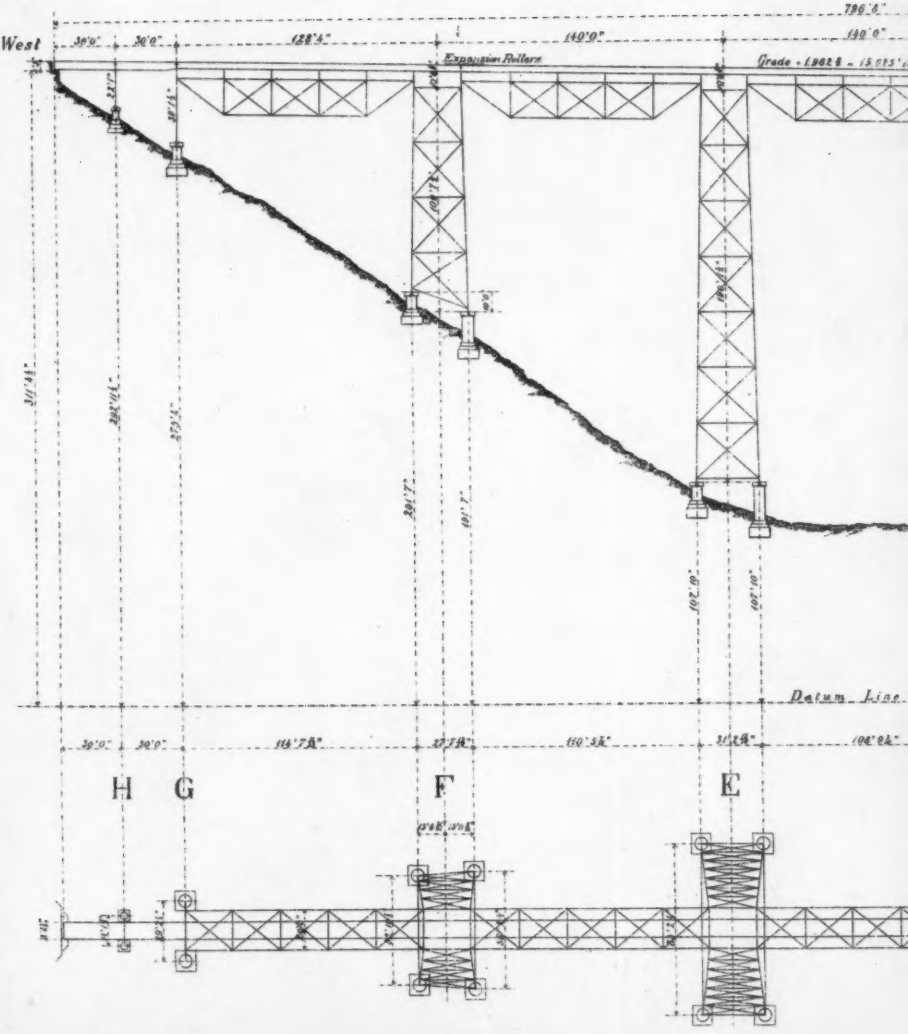
Plates LXXV and LXXVI are views during the erection and after the completion of the viaduct.

N. P. R

MARENT V

*General Elevat*

*Scale*



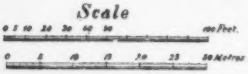
N. P. R.R.

# MARENT VIADUCT

*General Elevation and Plan.*

PLAT
TRANS.AM
VOL.
MO
THE MAREN

*Scale*



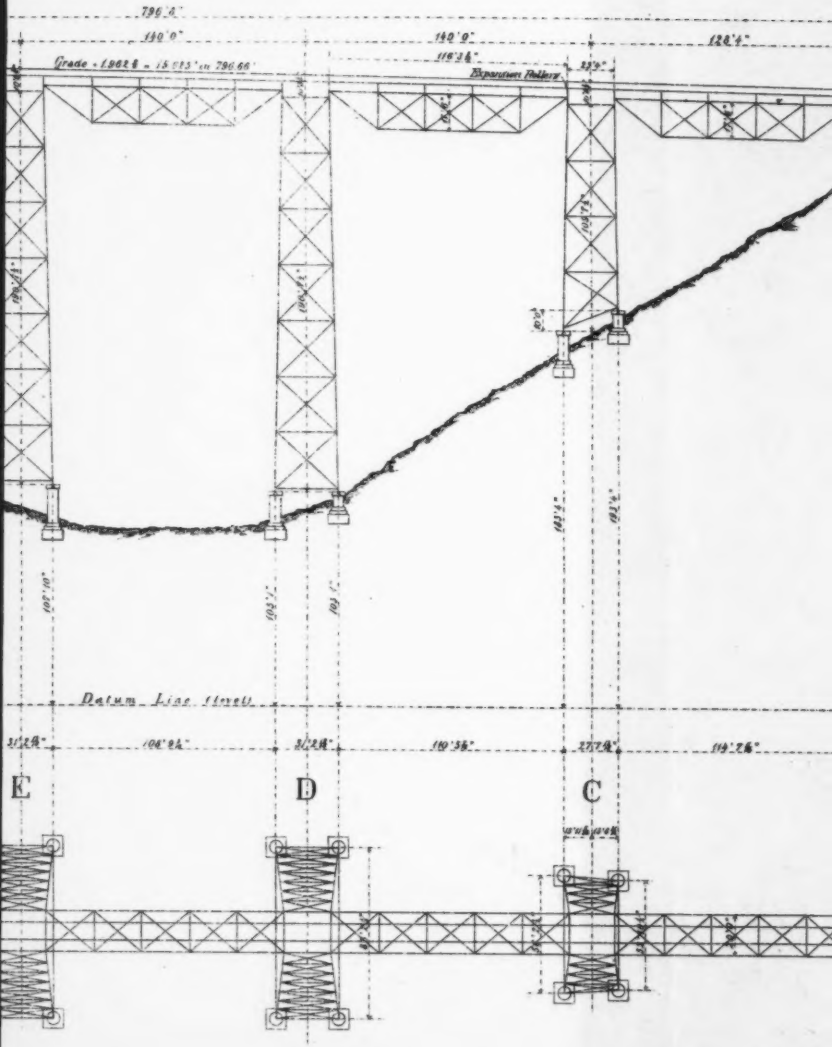



PLATE LXIII
TRANS. AM. SOC. CIV. ENG'RS.
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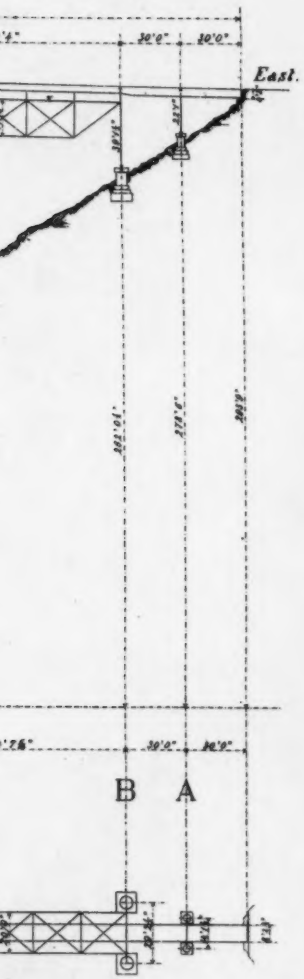
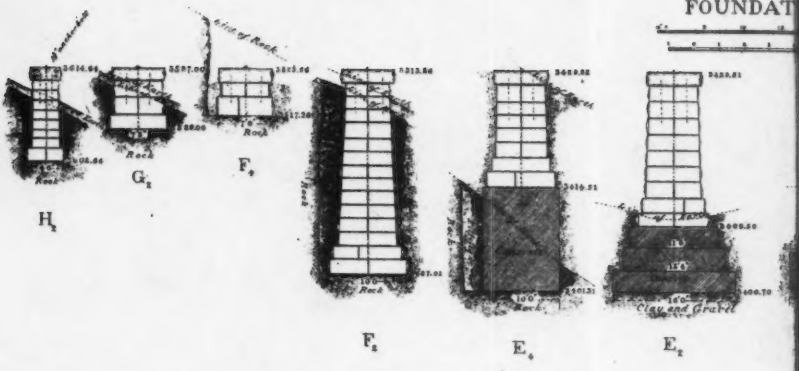
MORISON ON
E MARENT GULCH VIADUCT.

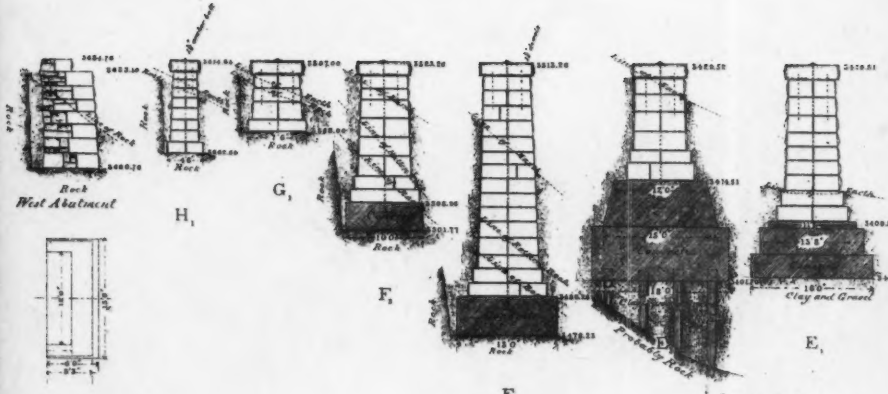


N. P. R.

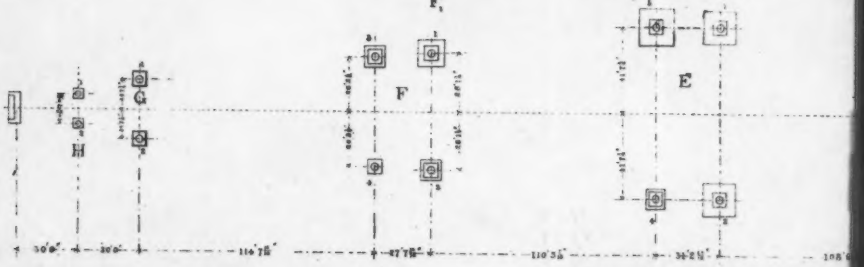
# MARENT V

MASON
and
FOUNDAT



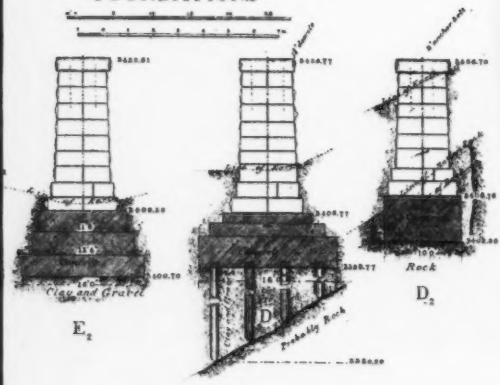


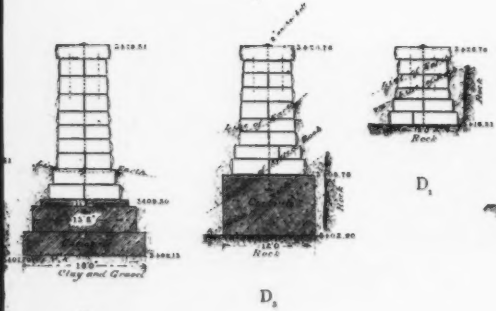
N. P. R. R.

# MARENT VIADUCT.

## MASONRY and FOUNDATIONS




$E_2$ $D$ $D_2$ $C_2$ $B_2$




$E_1$ $D_1$ $C_1$ $B_1$

$D_2$ $C_2$

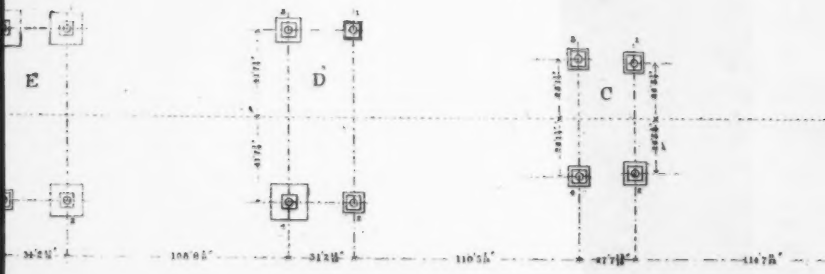
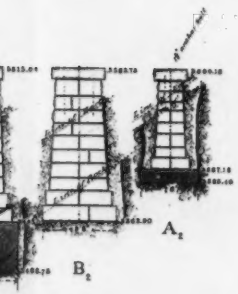
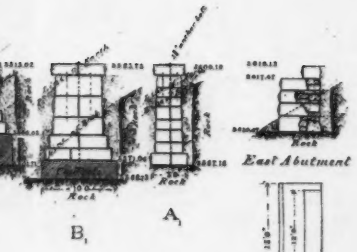


PLATE LXIV
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXV. Nº 500.
MORISON ON
THE MARENT GULCH VIADUCT.

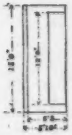


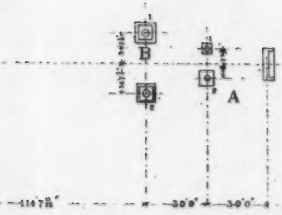



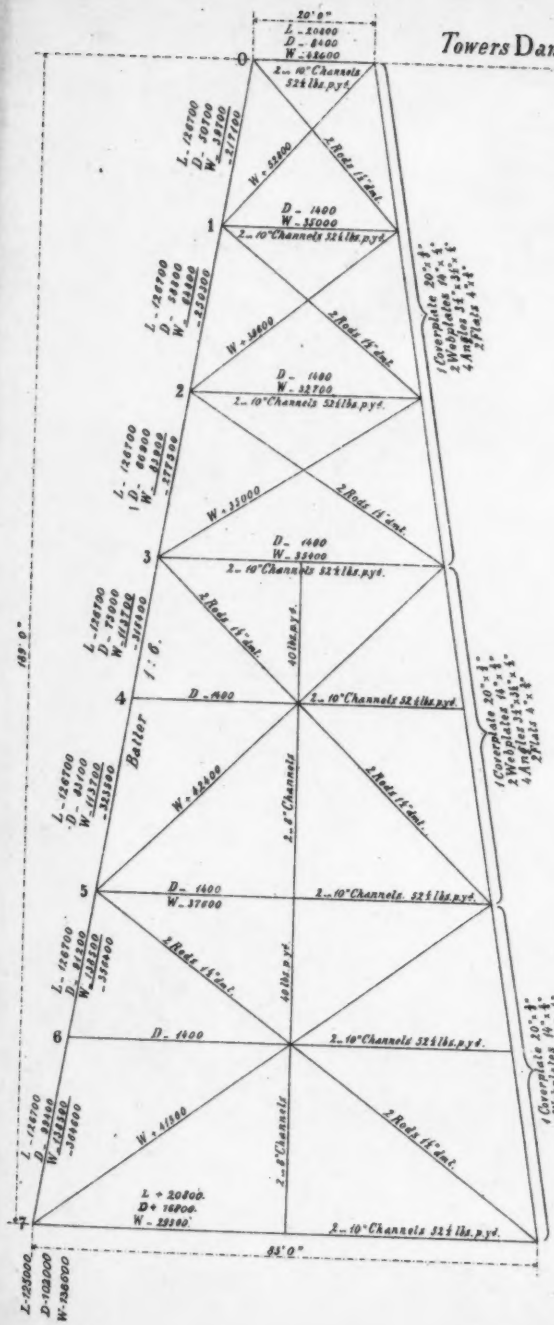




East Abutment






Towers D and E
20'0"
L - 20400
D - 8400
W - 28800
0
2 - 10" Channels 52½ lbs. p.y.d.
L - 128700
D - 50100
W - 32700
- 211700
W - 32800
2 Rods 1¼" Ext.
1
D - 1400
W - 32000
2 - 10" Channels 52½ lbs. p.y.d.
L - 128700
D - 51100
W - 83800
- 263600
W - 34000
2 Rods 1¼" Ext.
2
D - 1400
W - 32700
2 - 10" Channels 52½ lbs. p.y.d.
L - 128700
D - 60900
W - 83800
- 273300
W - 33000
2 Rods 1¼" Ext.
3
D - 1400
W - 32900
2 - 10" Channels 52½ lbs. p.y.d.
L - 128700
D - 72000
W - 84700
- 285400
W - 33400
2 Rods 1¼" Ext.
40 lbs. p.y.d.
4
D - 1400
2 - 10" Channels 52½ lbs. p.y.d.
Batter 1:6.
L - 128700
D - 83100
W - 84700
- 296500
W - 34400
2 - 8" Channels
2 Rods 1¼" Ext.
5
D - 1400
W - 37800
2 - 10" Channels 52½ lbs. p.y.d.
L - 128700
D - 91200
W - 84700
- 304600
W - 35400
2 Rods 1¼" Ext.
40 lbs. p.y.d.
6
D - 1400
2 - 10" Channels 52½ lbs. p.y.d.
L - 128700
D - 98400
W - 84700
- 311800
W - 41800
2 - 8" Channels
2 Rods 1¼" Ext.
7
L = 20800.
D + 16900.
W - 29300.
2 - 10" Channels 52½ lbs. p.y.d.
95'0"
L - 1235000.
D - 1031000.
W - 1386000.
185'0"
1 Coverplate 20" × ¾"
2 Webplates 14" × ⅜"
2 Angles 3½" × 3½" × ½"
2 Plate 4" × ½"
1 Coverplate 20" × ¾"
2 Webplates 14" × ⅜"
2 Angles 3½" × 3½" × ½"
2 Plate 4" × ½"
1 Coverplate 20" × ¾"
2 Webplates 14" × ⅜"
2 Sideplates 7" × ⅜"
4 Angles 3½" × 3½" × ½"
2 Plate 4" × ½"
23'6"
T - 24300
2 - 10" Channels 52½ lbs. p.y.d.
T - 36100
2 Rods 1¼" Ext.
T - 23200
2 - 10" Channels 52½ lbs. p.y.d.
T - 33600
2 Rods 1¼" Ext.
T - 22200
2 - 10" Channels 52½ lbs. p.y.d.
T - 31500
2 Rods 1¼" Ext.
T - 21300
2 - 10" Channels 52½ lbs. p.y.d.
T - 29100
2 Rods 1¼" Ext.
T - 20400
2 - 10" Channels 52½ lbs. p.y.d.
T - 27800
2 Rods 1¼" Ext.
T - 18600
2 - 10" Channels 52½ lbs. p.y.d.
T - 26300
2 Rods 1¼" Ext.
T - 18000
2 - 10" Channels 52½ lbs. p.y.d.
T - 24800
2 Rods 1¼" Ext.
T - 18200
2 - 10" Channels 52½ lbs. p.y.d.
27'0"
32'0"
54'0"
56'0"
Batter 1:48
T - 27200
M - 244300
T - 32000
M - 302300
T - 31700
M - 352100
T - 31000
M - 411000
T - 30400
M - 471400
T - 30400
M - 532100
T - 29700
M - 592800
T - 29400
M - 653100
T - 29400
M - 713800
T - 29400
M - 774500
T - 29400
M - 835200
T - 29400
M - 895900
T - 29400
M - 956600
T - 29400
M - 1017300
T - 29400
M - 1078000
T - 14900.

N. P. R. R.

# MARENT VIADUCT

Towers C and

Scale

0 5 10 20 30 40 50 Feet.

0 1 2 3 4 5 10 15 Metres.

## Strains and Sections of Towers.

L = Strains due to Live Load of 125000 lbs. at 0

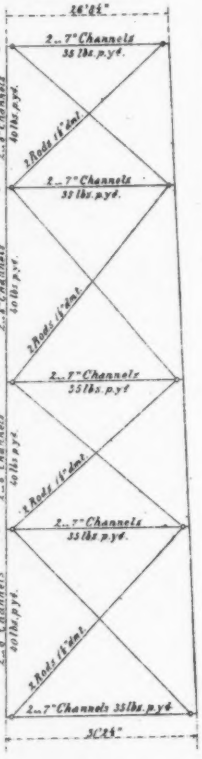
D = " " " Dead " of 50000 " at 0
and 8000 " at 1,2 etc

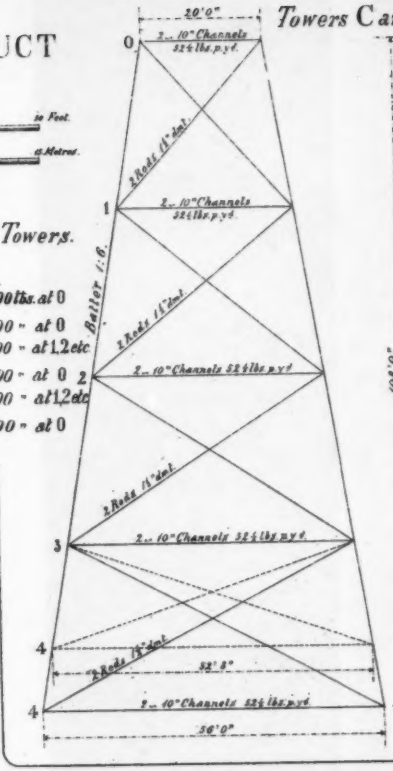
W = " " " Wind Pressure of 42000 " at 0 2
and 6000 " at 1,2 etc

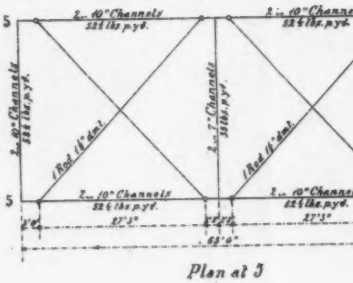
T = " " " Traction of 24500 " at 0

M = " " " L.D.W.ST.

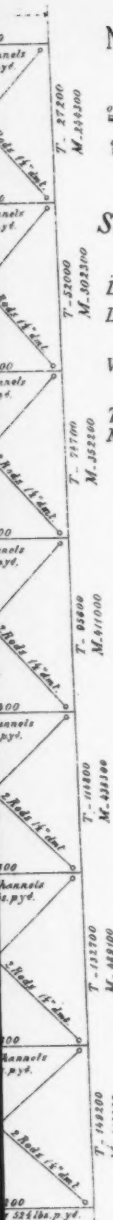
Central Section.



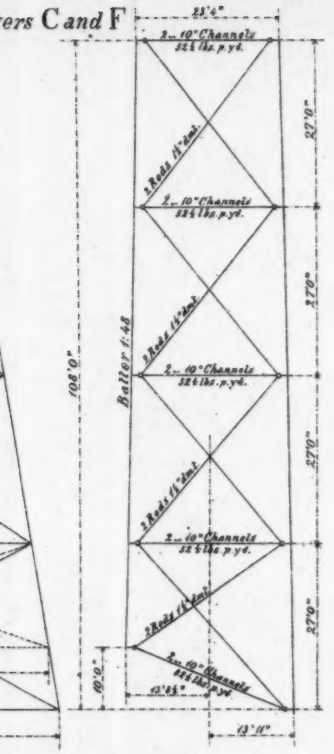



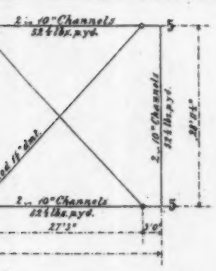




Plan at 5

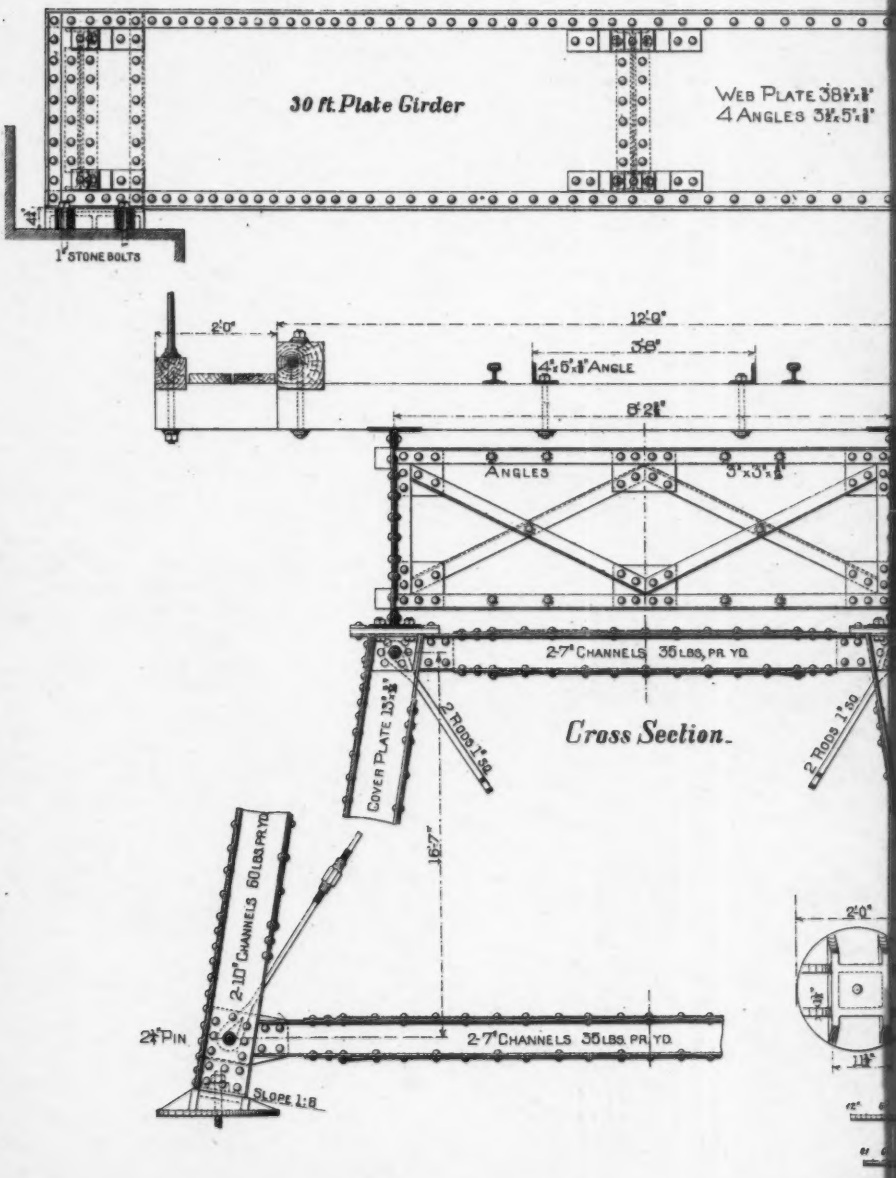


...ers C and F


23'4"
2 - 10" Channels
32½ lbs. p. yd.
2 Rods 1¼" sq.
27'0"
Batter 1:48
100'0"
13'11"


2 - 10" Channels
32½ lbs. p. yd.
27'3"

## *Details of Plate Girders and Bents.*



N. P. R. R.

# MARENT VIADUCT

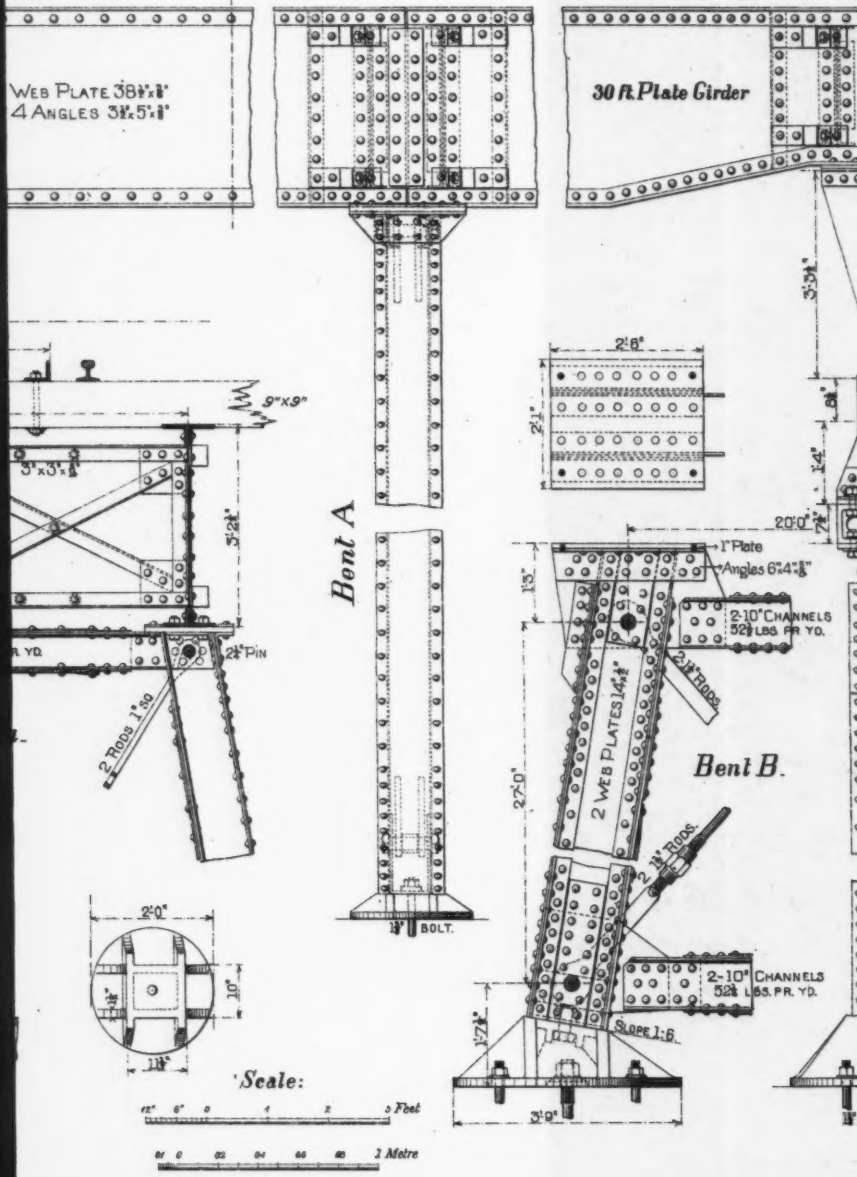


PLATE LXVI
TRANS. AM. SOC. CIV. ENG'RS.
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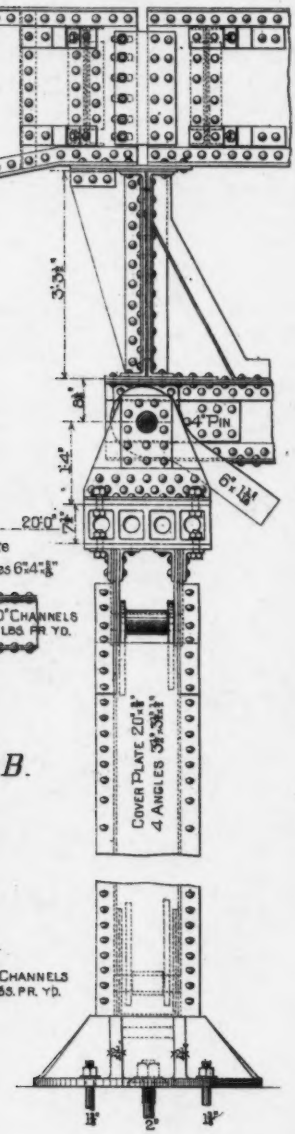
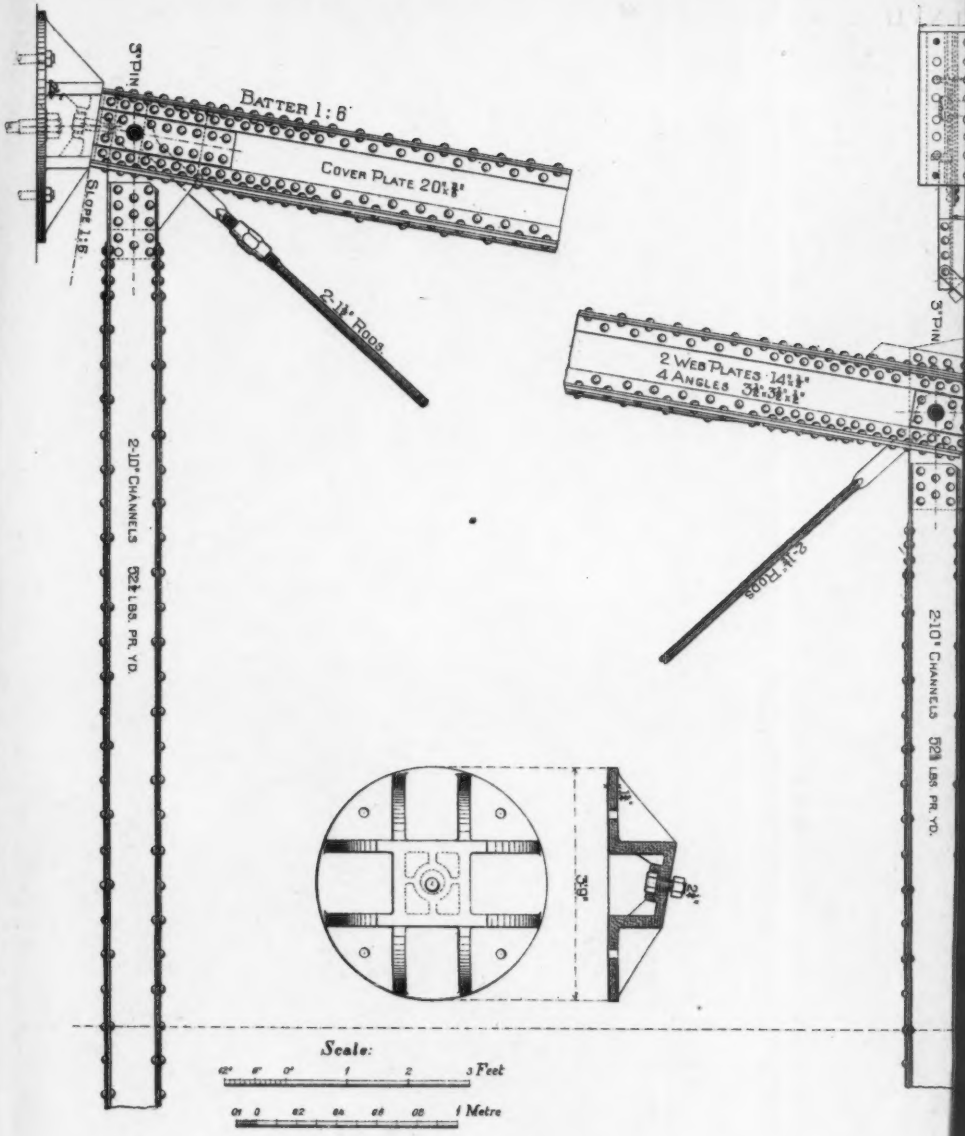
MORISON ON
HE MARENT GULCH VIADUCT.




B.


3" PIN
BATTER 1:6
COVER PLATE 20½"
SLOPE 1:6
2-½" RODS
2-10" CHANNELS 32½ LBS. PR. YD.
3" PIN
2 WEB PLATES 14½"
4 ANGLES 3½"×3½"×½"
2-1" RODS
2-10" CHANNELS 32½ LBS. PR. YD.
3'0"
Scale:
3 Feet
1 Metre

N. P. R. R.

# MARENT VIADUCT

*Cross Section at Bent B.*

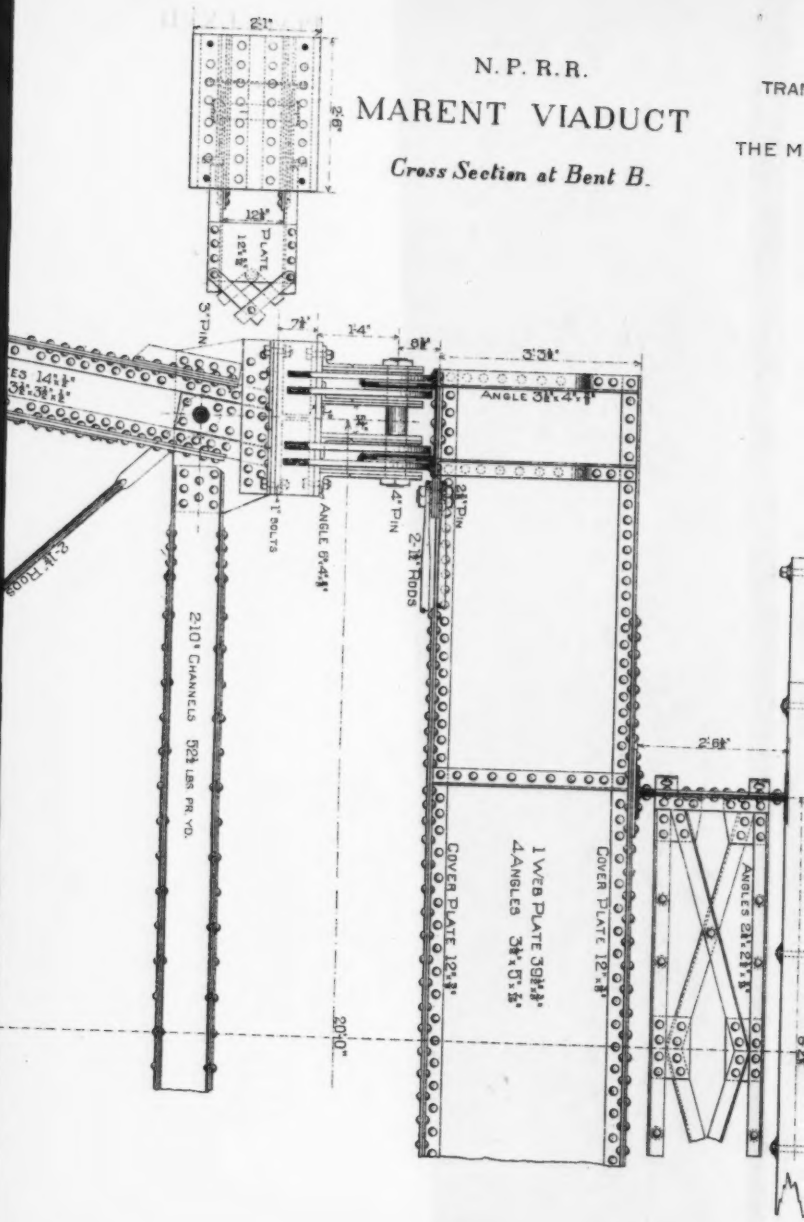


PLATE LXVII
TRANS. AM. SOC. CIV. ENG'RS.
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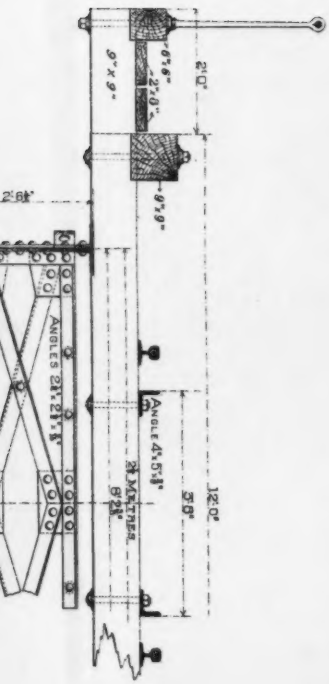
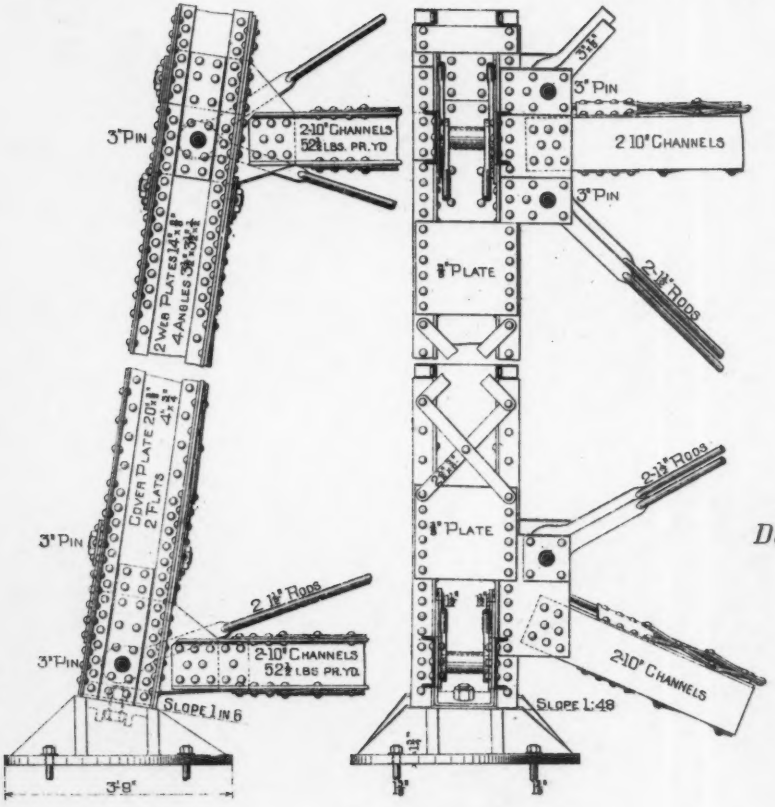
MORISON ON
THE MARENT GULCH VIADUCT.



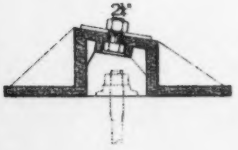
*Tower C & F*

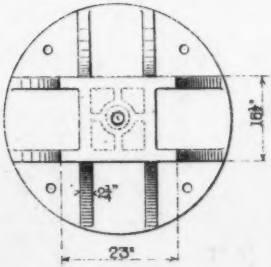
N. P. R. R.

MARENT VIAD



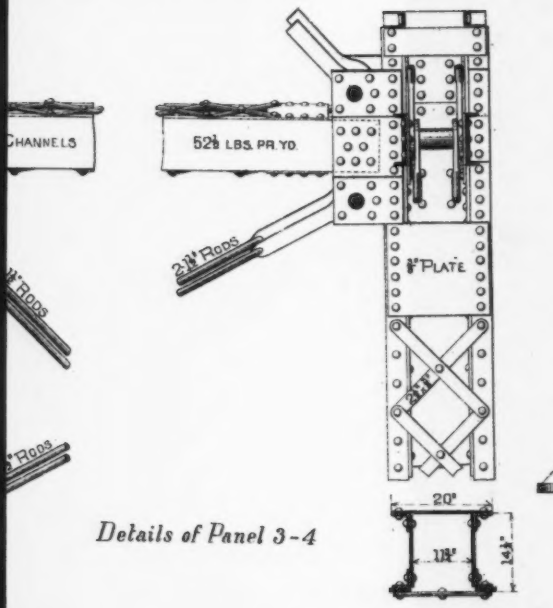

*Details of P*



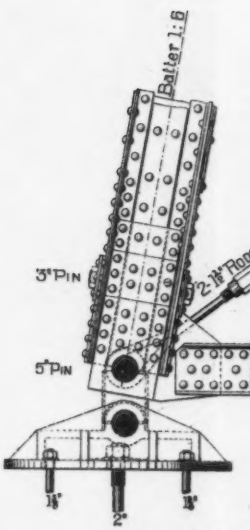



N. P. R. R.

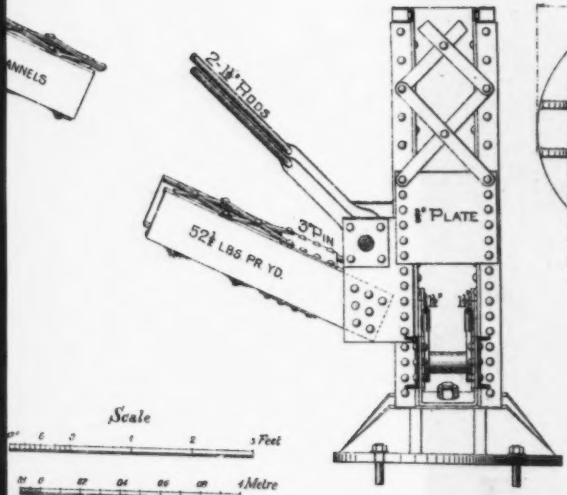
# ARENT VIADUCT




*Details of Panel 3-4*




*Detail*



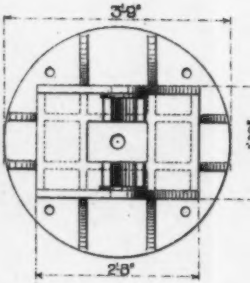



PLATE LXVIII
TRANS. AM. SOC. CIV. ENG'RS.
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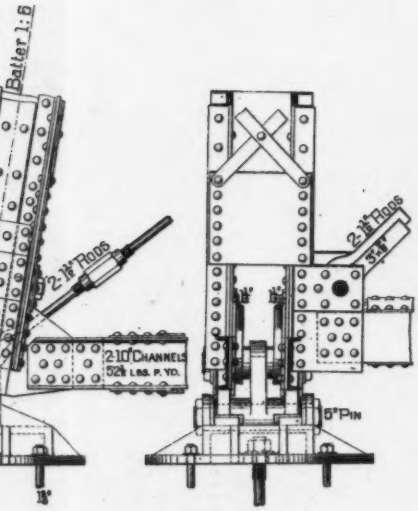
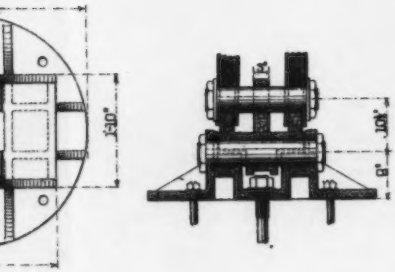
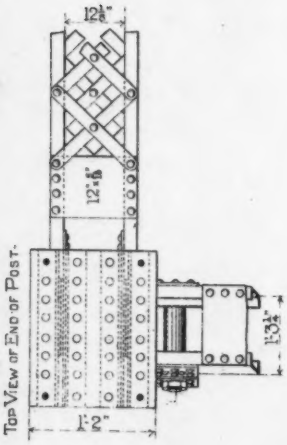
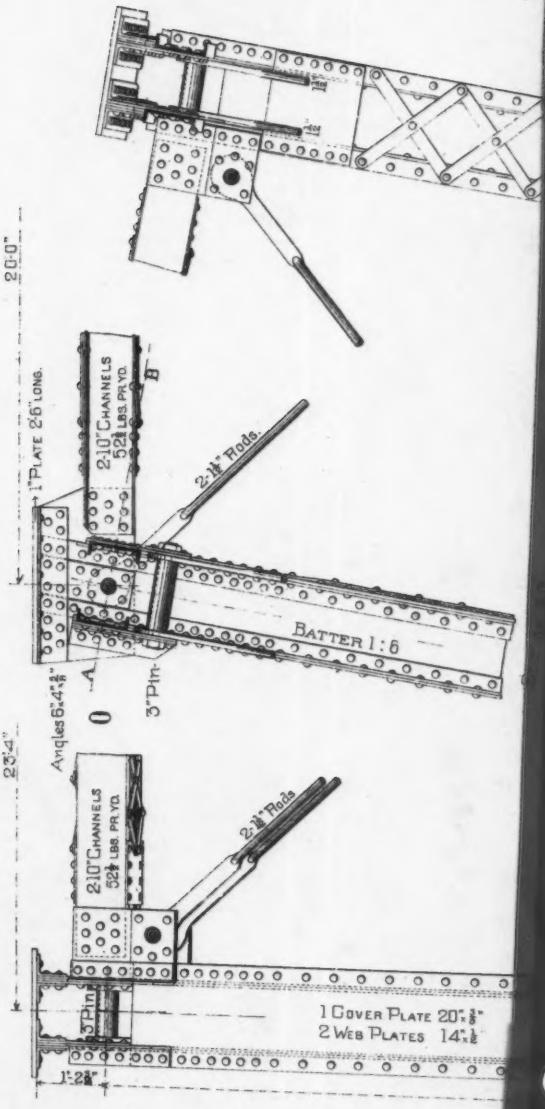
MORISON ON
THE MARENT GULCH VIADUCT.




*Details of Rocker*





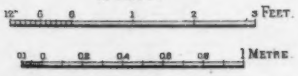




N.P.R.R.

# MARENT VIADUCT

## *Details of Towers* D *and* E.

*Scale:*



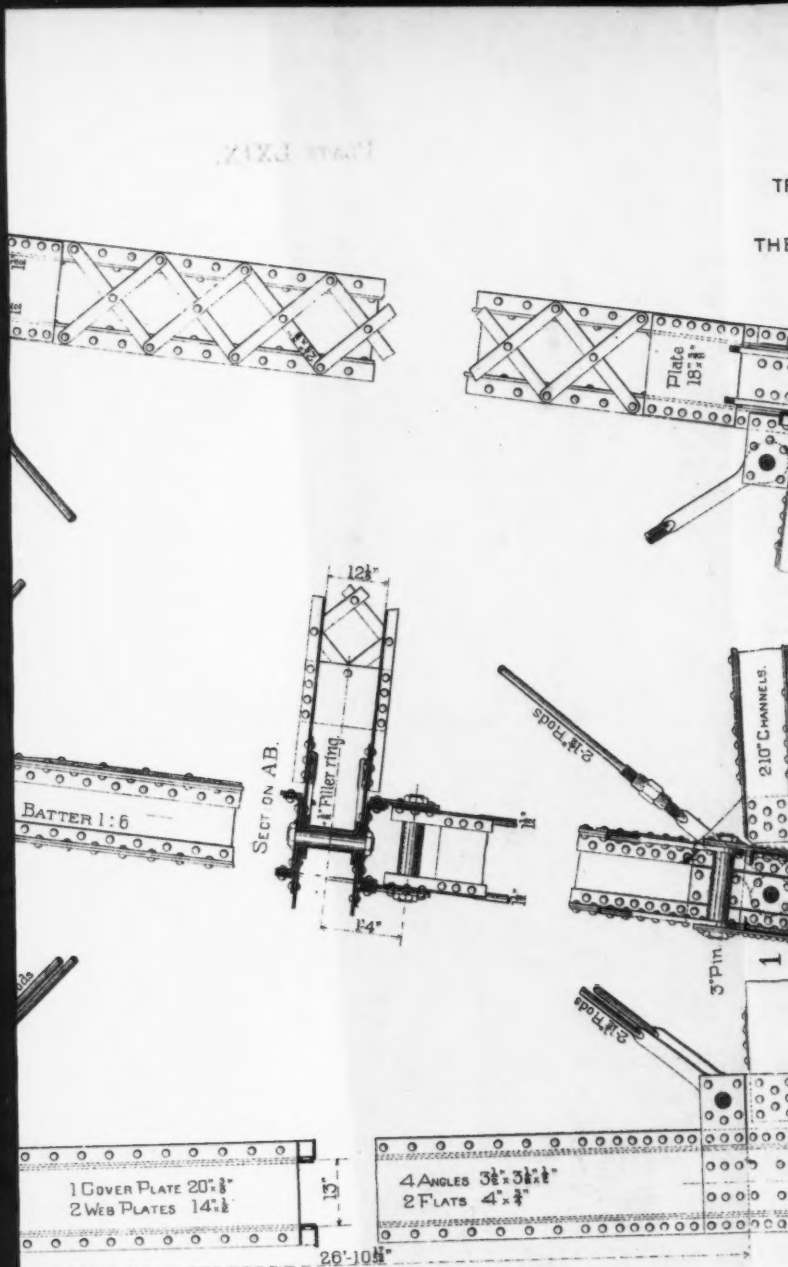


Plate 15"
12½"
1" Filler ring
SECT ON AB.
BATTER 1:6
2-18"Rods
210" CHANNELS.
3" Pin
2-18"Rods
1 COVER PLATE 20"
2 WEB PLATES 14"
13"
4 ANGLES 3½"×3½"
2 FLATS 4"×
26'-10

PLATE LXIX
TRANS. AM. SOC. CIV. ENG'RS.
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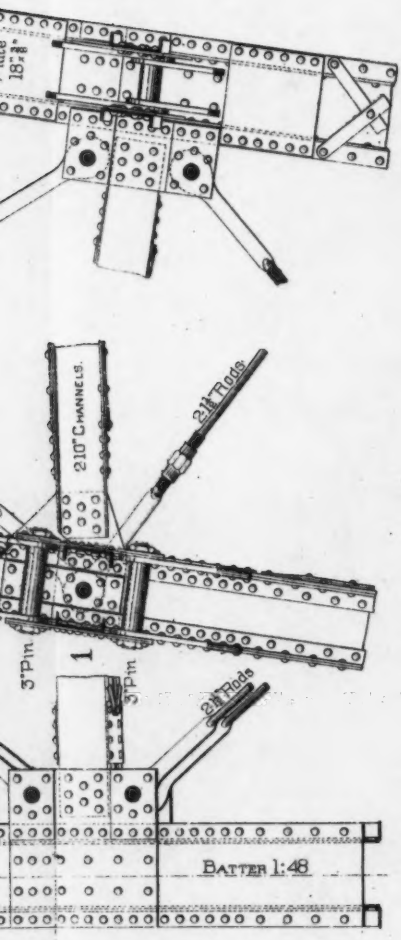
MORISON ON
THE MARENT GULCH VIADUCT.



*Details of Towers* D *and* E.

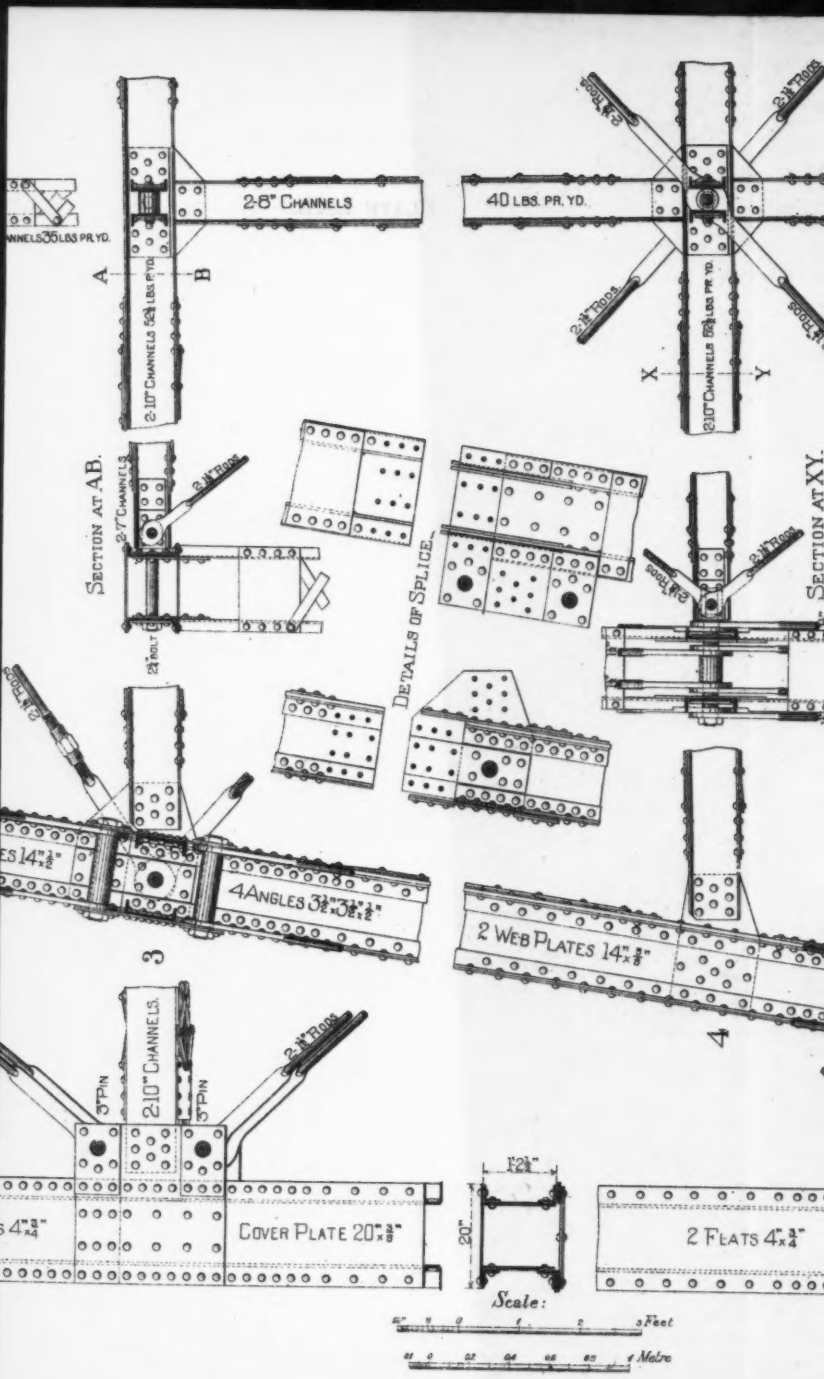

2-8" Channels
40 lbs. pr. yd.
2-10" Channels 53½ lbs. pr. yd.
A
B
X
Y
Section at AB.
Section at XY.
Details of Splice.
2-7" Channels
2-½" Rods
2-½" Bolts
4 Angles 3½"×3½"×½"
2 Web Plates 14"×⅜"
2-10" Channels.
3" Pin
Cover Plate 20"×⅜"
2 Flats 4"×¾"
20"
Scale:
3 Feet
1 Metre

PLATE LXX
TRANS. AM. SOC. CIV. ENG'RS.
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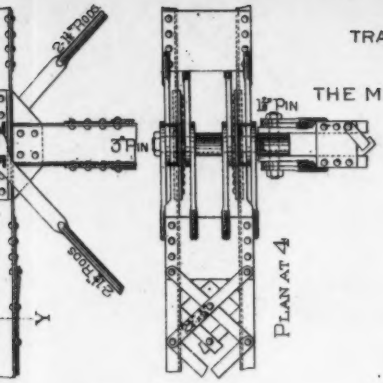
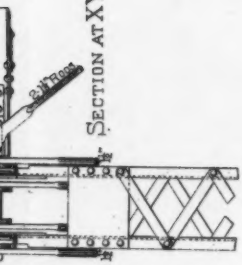
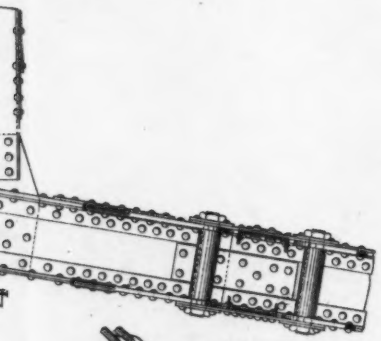
MORISON ON
THE MARENT GULCH VIADUCT.

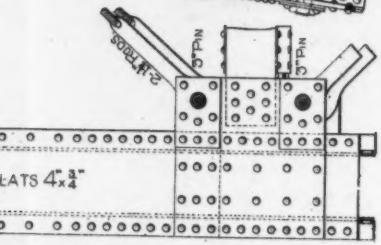


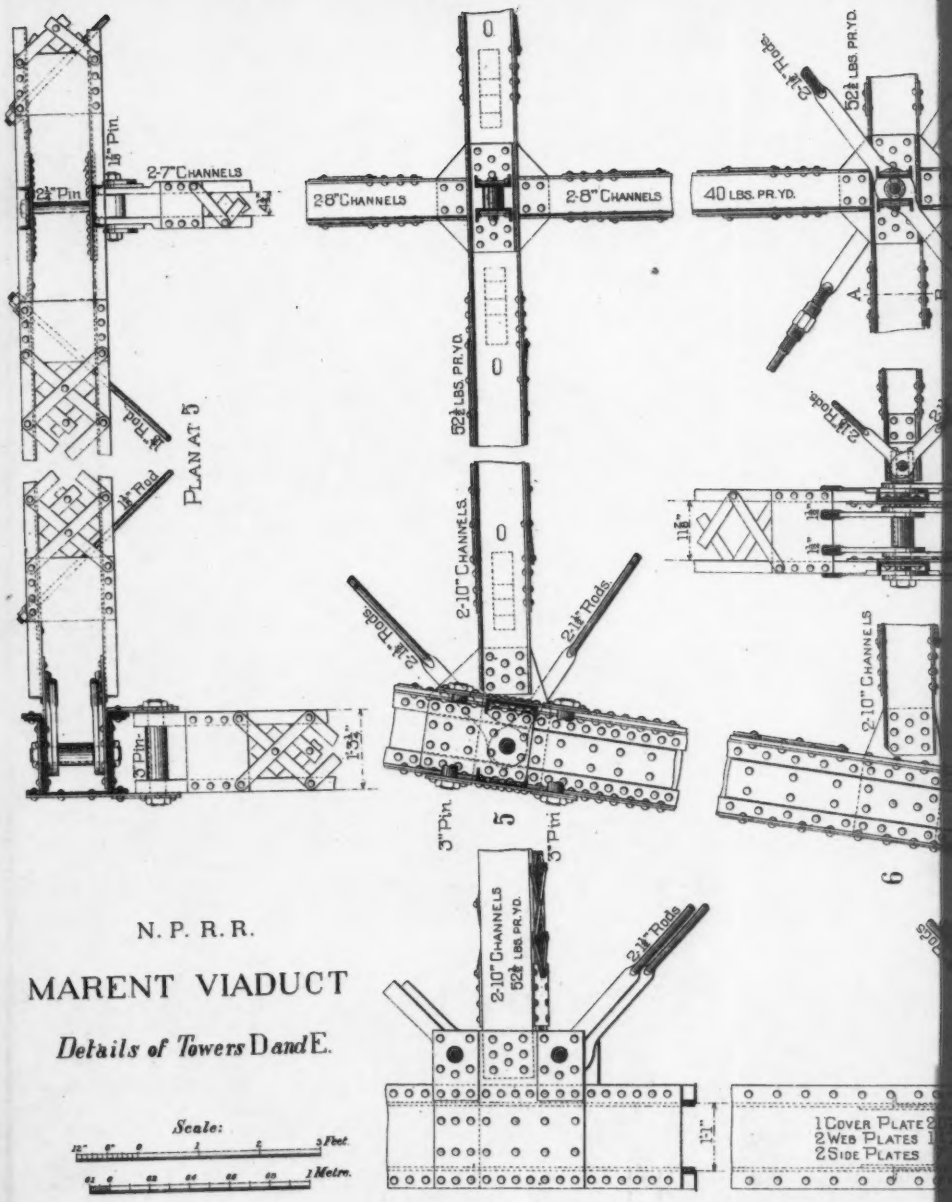











N. P. R. R.

# MARENT VIADUCT

*Details of Towers D and E.*

Scale:

3 Feet.

1 Metre.

PLATE LXXI
TRANS. AM. SOC. CIV. ENG'RS.
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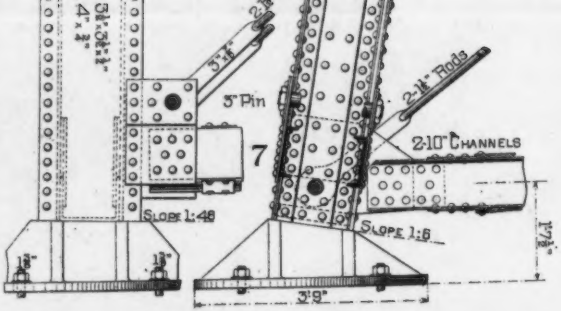
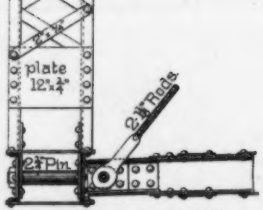
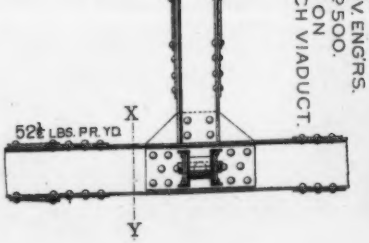
MORISON ON
THE MARENT GULCH VIADUC

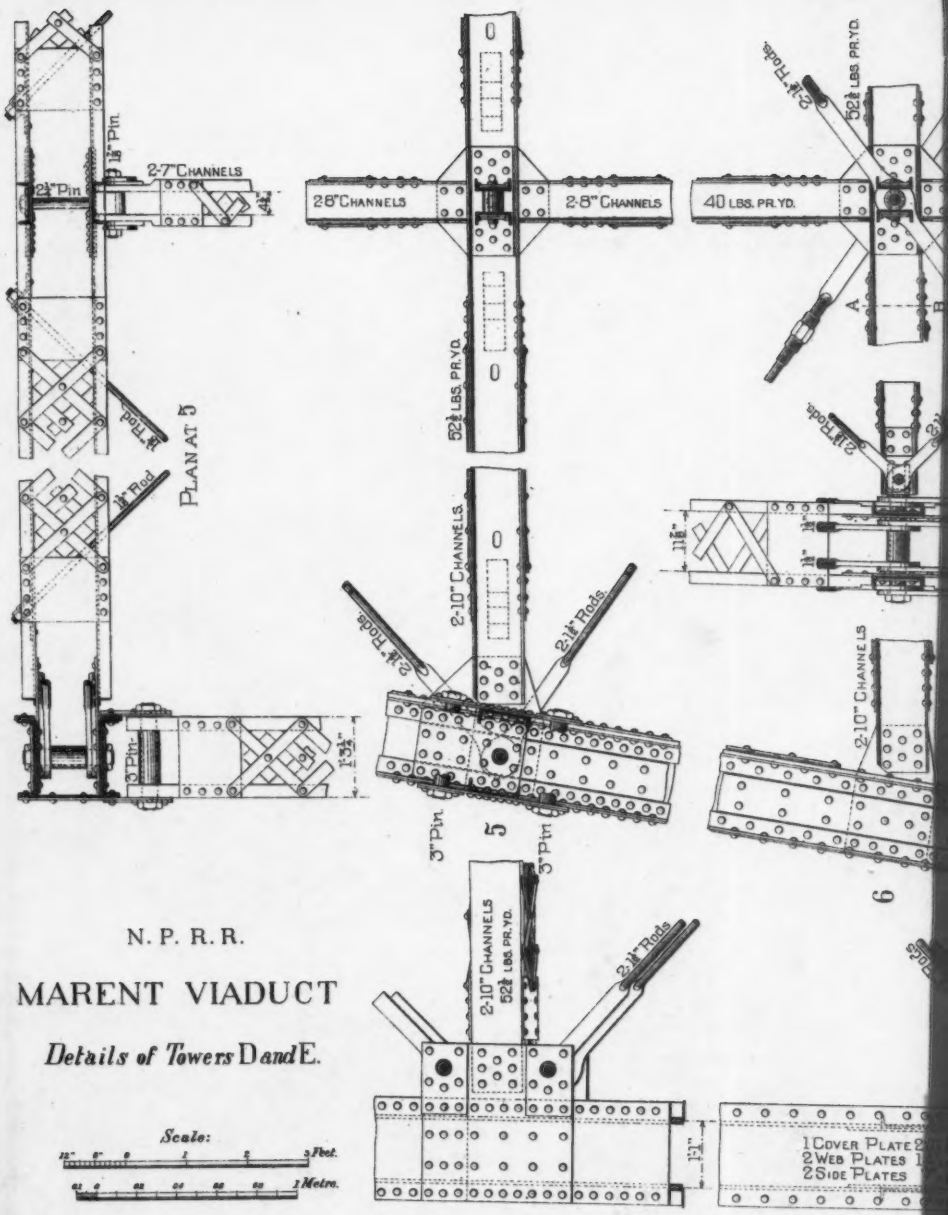



SECTION AT XY.




V. ENG'RS.
500.
ON
CH VIADUCT.




N. P. R. R.

# MARENT VIADUCT

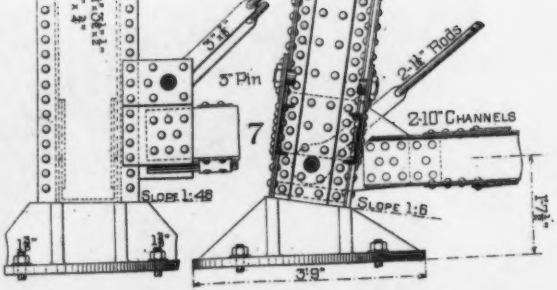
*Details of Towers D and E.*

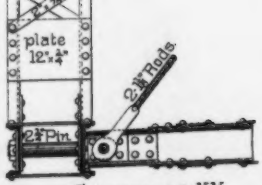
Scale:

12" 6" 0 1 2 3 Feet.

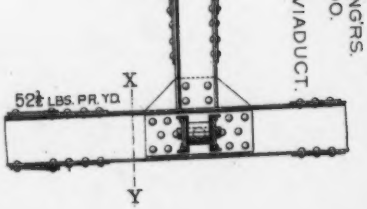
.2 0 .2 .4 .6 .8 1 Metre.

PLATE LXXI
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXV. N° 500.
MORISON ON
THE MARENT GULCH VIADUCT.




Section at XY.




ENG'RS.
O.
VIADUCT.

N. P. R. R.

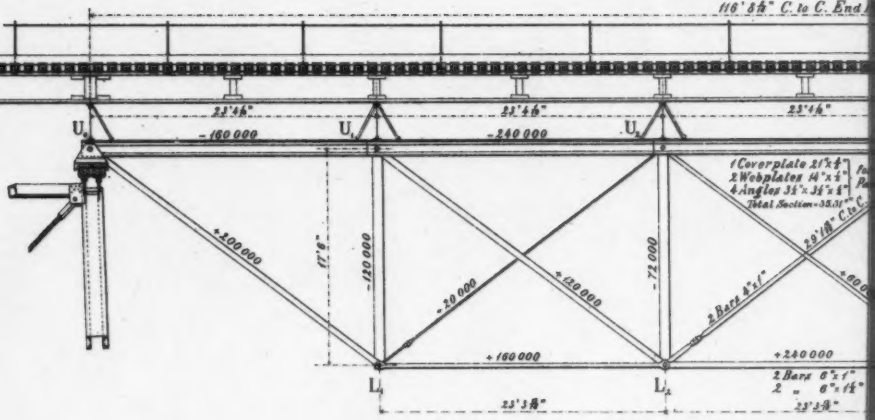
# MARENT VIA

Scale

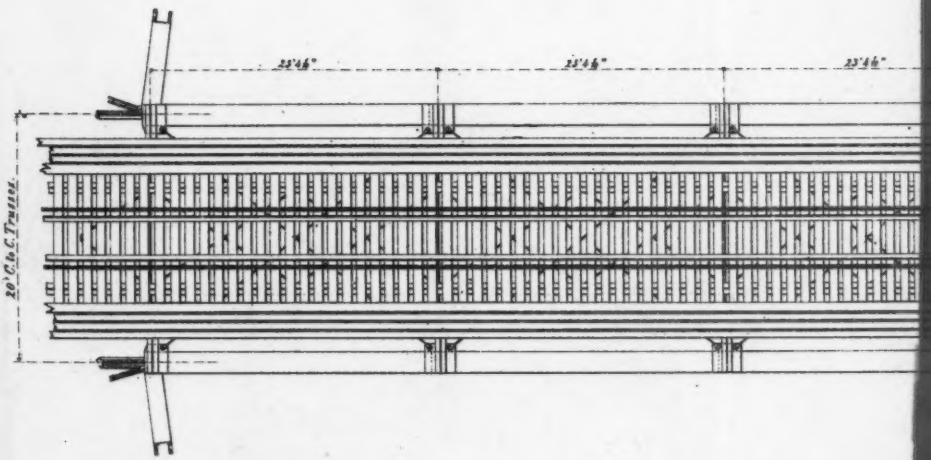
0 1 2 3 4 5 10 15

0 Ø.5 1 2 3 4

*General Elevation and Pla*




*Panel Load 60,000 lbs for each Truss, all treate*



N. P. R. R.

# MARENT VIADUCT

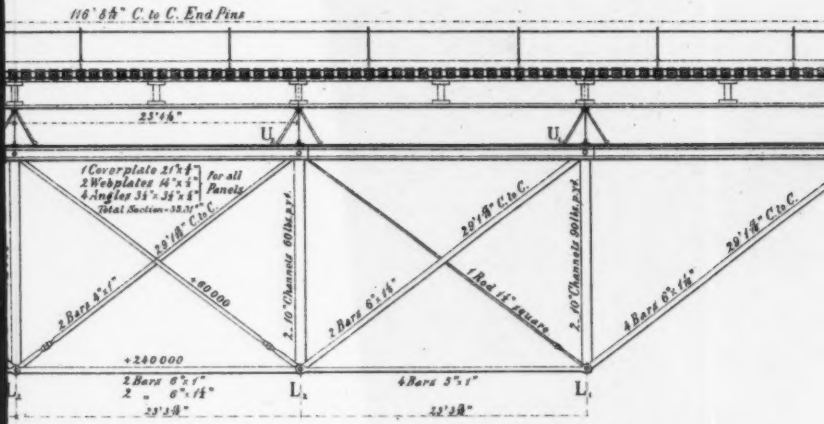
PLATE
TRANS. AM. SO
VOL. XX
MORIS
THE MARENT

Scale

0 1 2 3 4 5 10 15 20 Feet

0 0.5 1 2 3 4 5 6 Metres

## ...al Elevation and Plan of Deck Span




## ...or each Truss, all treated as Moving Load.

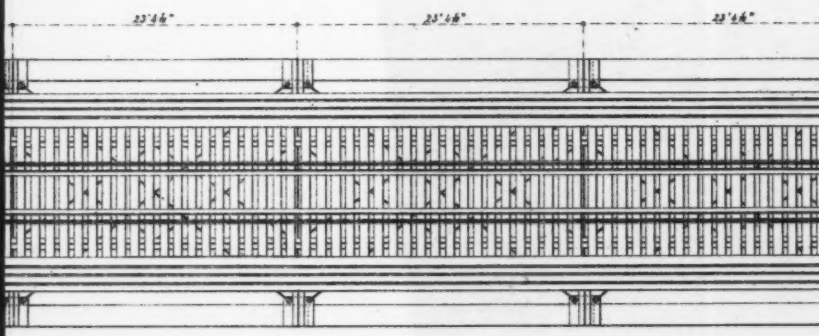


PLATE LXXII
TRANS. AM. SOC. CIV. ENG'RS.
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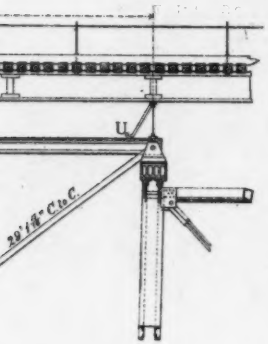
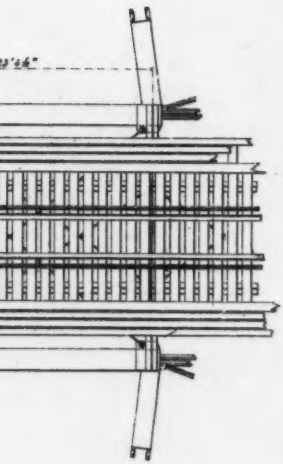
MORISON ON
MARENT GULCH VIADUCT.

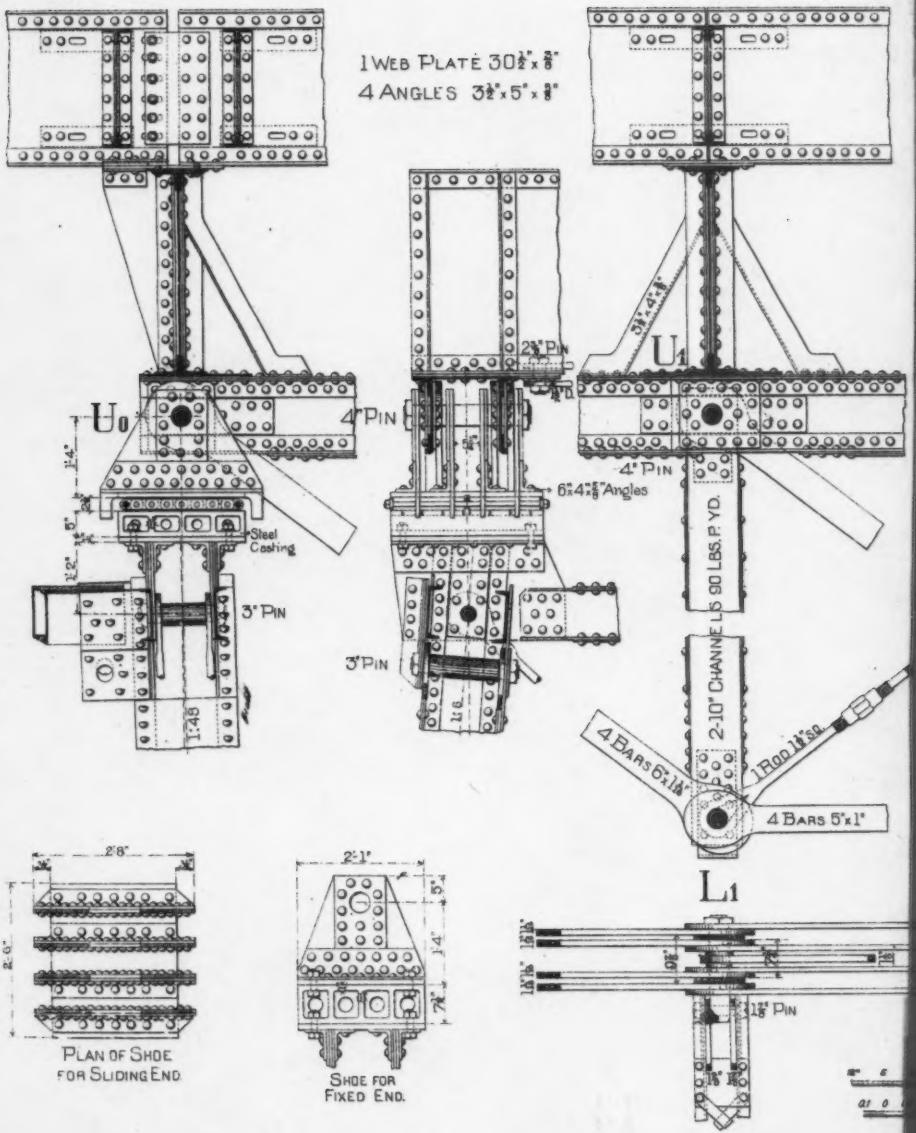


*Details of Deck Span*

N. P. R. R.

MARENT VIADU



N. P. R. R.

MARENT VIADUCT

TRA

THE N

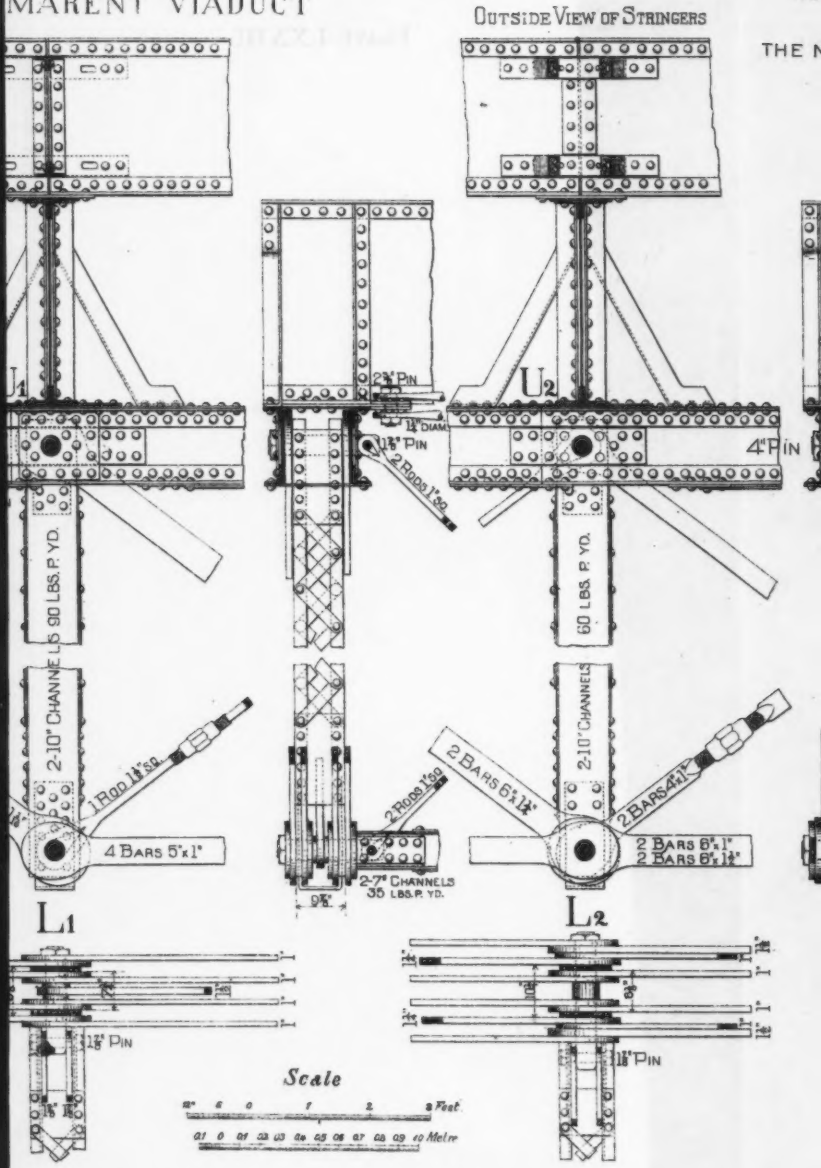


PLATE LXXIII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXV. Nº 500.
MORISON ON
THE MARENT GULCH VIADUCT.

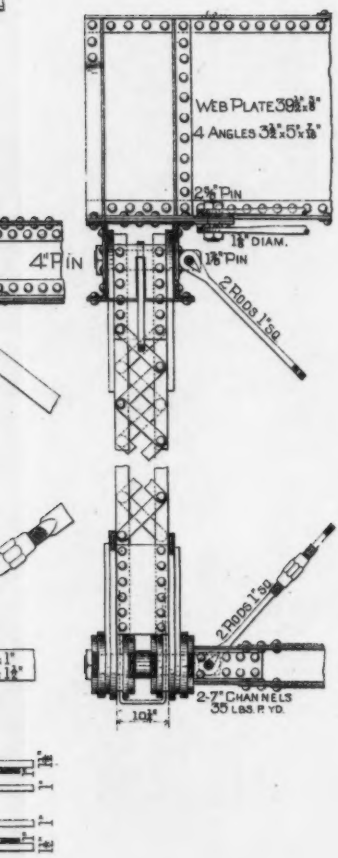


PLATE LXXIV.
TRANS. AM. SOC. C. E.
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MORISON ON THE MARENT GULCH VIADUCT.

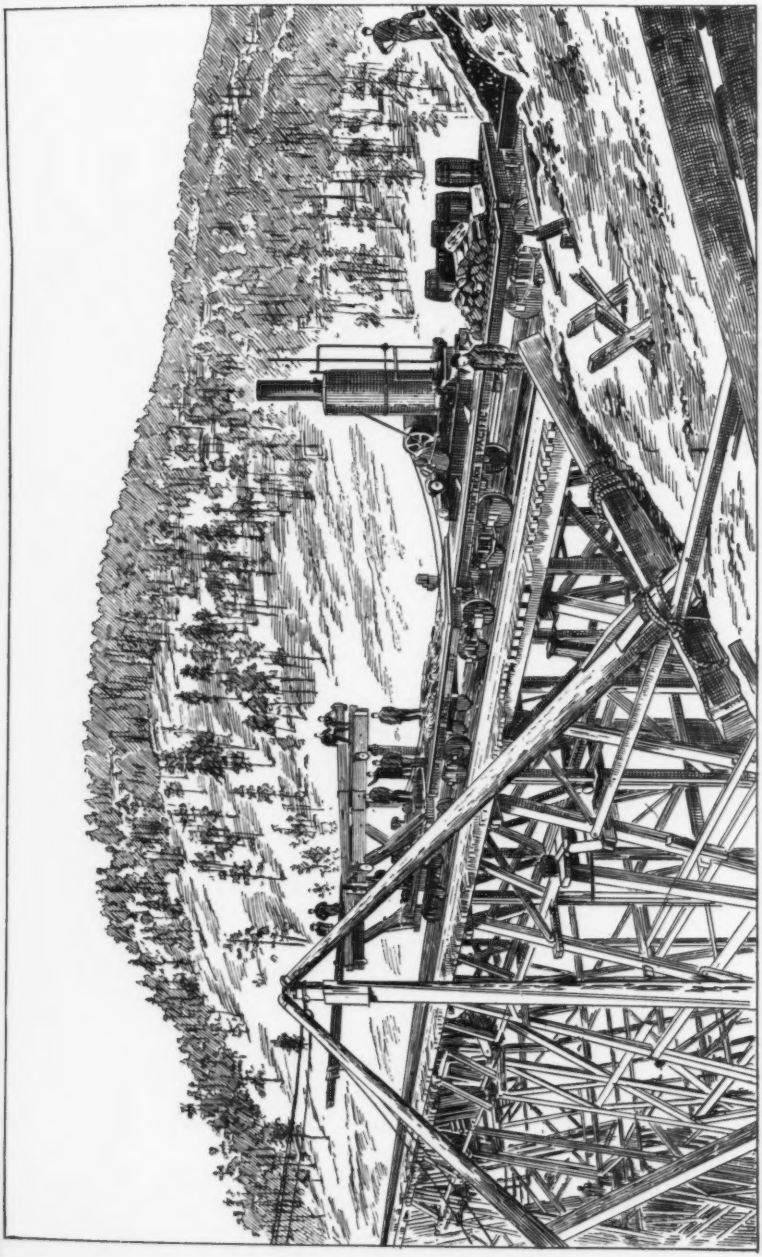
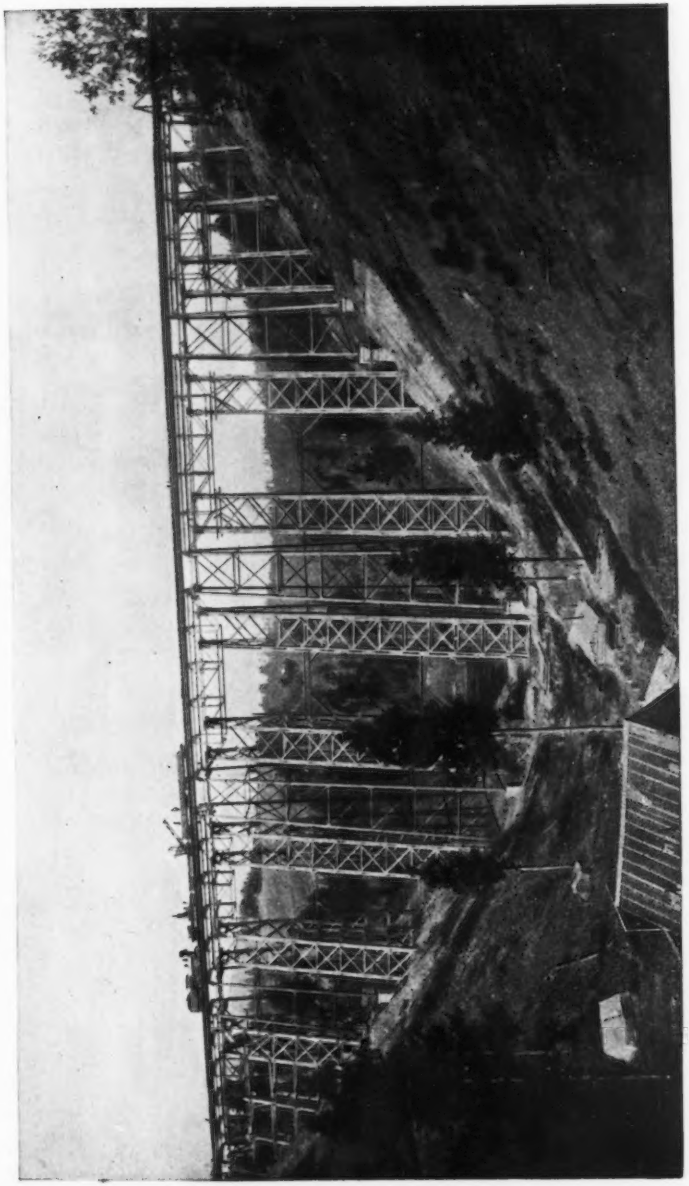
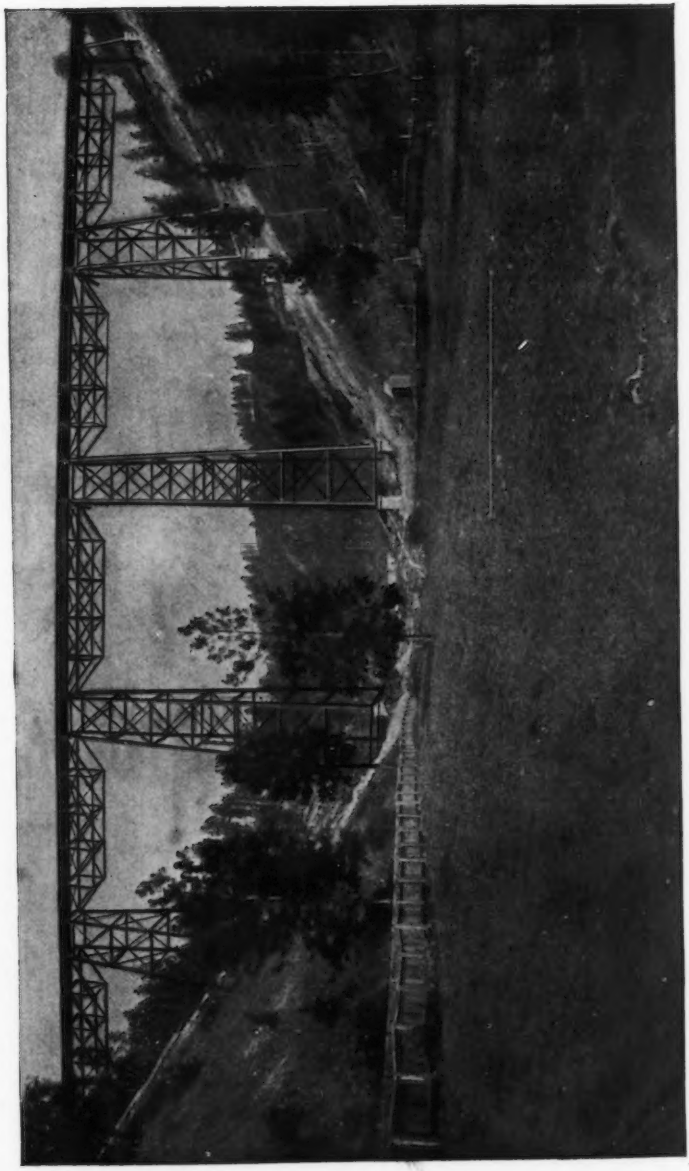


PLATE LXXV.
TRANS. AM. SOC C. E.
VOL. XXV, NO. 500.
MORISON ON THE MARENT GULCH VIADUCT.





AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

501.

(Vol. XXV.—September, 1891.)

# RIGHT OF WAY FOR RAILROADS.

By JULIEN A. HALL, M. Am. Soc. C. E.

## WITH DISCUSSION.

This very important department of railroad work does not always receive the attention it merits, and until recently it has been somewhat neglected. This has been largely due to the fact that property owners have generally been only too glad to promise the right of way free, in order that the railroads might be built, knowing how much the value of their property would be enhanced thereby; while the presidents of the roads have had in view the rapid, and at the same time economical, construction of their lines, and have not always taken the precaution to secure the necessary title to the property occupied. The result is, that after the lapse of years, during which the property has, by reason of the construction of the road through it, largely increased in value, the owner fails to remember that he gave the right of way and makes a determined effort to get pay for it; or, if he is forced to remember it, he remembers also that there were certain conditions in the grant with which the company has failed to comply, and, in collusion with a lawyer, enters suit against the company, generally succeeding in getting from five to ten times the value of the property taken.

The right of way for lines built during the last few years has, however, received much better attention, and in the future will probably give little or no trouble. One of the things with which we now have to contend is the considerable amount of right of way for which no settlement has ever been made, and in this, the only thing the railroad company can do is to wait for claims to be made and then compromise as best it can. It has been thought that occupancy of land by a railroad for a term of years gives it a title to the land, but a recent decision has shown that this belief is incorrect, and that a railroad can acquire land only by settlement with the owner or by condemnation. Another matter which sometimes gives a good deal of trouble is to prove the ownership, even where the title has apparently been acquired. On referring the case to the individual who is supposed to be the proper custodian of the titles to all property owned by a company, it is often found that by some carelessness he has not in his possession the deed making the conveyance, and then comes an exhaustive and sometimes rather expensive search through the court records for the information required. The best man to make this search is an engineer experienced in such work, and every road liable to have claims made against it on account of unsettled right of way should have such a man in its employ. He can be promptly detailed to look into such matters, meet the party making the claim, and compromise with him before a lawyer can interfere, and by acting promptly as indicated, the company can nearly always accomplish its purposes and save money. There are a great many engineers who refuse to have anything to do with securing right of way, claiming that such work is out of their line. It is, however, largely to the interest of the company to employ an engineer who has good business judgment, as well as engineering knowledge, to have it understood that the right of way is to be secured and put in proper shape under his direction, and to give him as his right of way agent an honest, competent, business man. This man should report to the chief engineer only, who should be empowered to make on a prescribed basis such settlements for right of way as he may deem proper and for the best interests of the company. As settlements are made, the deeds should be immediately recorded, and after the Chief Engineer has had a copy of them made in his office they should be turned over to the secretary of the company. As the deeds are received by the chief engineer he should have his right of way maps completed, copies of which, when

required by law, he will have recorded at the court houses of the counties through which the line passes. The originals should be retained for file in the chief engineer's office, and with these and his copies of deeds he will be fully equipped to give prompt and satisfactory information pertaining to all right of way matters that may arise.

As soon as the preliminary survey for a railroad is begun, a right of way agent should be put in the field, whose duty it should be to secure signatures of property owners to an agreement, providing that so soon as the railroad is constructed, a proper deed for a right of way of prescribed width shall be given. The following is a form of agreement which has been approved by first-rate railroad lawyers.

## RIGHT OF WAY AGREEMENT.

"THIS AGREEMENT WITNESSETH: That for and in consideration of the advantages to be received by us respectively from the construction of the.....Railroad, across our lands, and in further consideration of one dollar in hand paid to each and every one of us, receipt of which is hereby acknowledged, we, the undersigned, hereby covenant and agree to and with the.....Railroad Company, that upon the location of the said..... Railroad across or upon our lands, in.....County, State of....., we will each for himself execute to the said .....Railroad Company, a sufficient deed to so much of our respective lands as shall be included between lines.....feet from and parallel to the center line of the road as it may be finally located by the company; and the agents and employees of the said company and the force engaged in surveying and constructing said railroad, are hereby permitted to enter upon said lands and locate and construct said railroad, and deeds shall be given so soon as the railroad shall be graded and track laid over each tract respectively, or as soon thereafter as shall be required."

NAME OF WITNESS. NAME OF DONOR. [SEAL.]

.....

..... .....

.....

In a section of country where the people are anxious for a road, nearly all of the signatures asked for can be readily obtained, and the agent soliciting the signatures should take in a considerable scope of

country on either side of the preliminary line, thus providing for any change of line that may afterward be found necessary.

Where there is an indisposition on the part of the land owners to sign the right of way agreement, the party making the survey should receive instructions to run several lines considerably diverging, and in doing this it will be found that securing the signatures will be a much less difficult matter. The signatures having been secured, the right of way papers should be recorded promptly in the court houses in the counties in which the signers live. This recording will, in some States, have the same effect as a deed, and prevent the signers from making over their right to the land to any one else, thus saving the company possible trouble by any change of titles or otherwise. Affidavits should be made in the agreement before it is recorded as follows:

"STATE OF....., } *ss.:*
..... County, }

"I,....., Notary Public, do certify that personally appeared before me this day,..... .....the subscribing witnesses to the signatures of:

(Signatures,)

.....

..... .....

to the contract to convey, hereto attached, witnessed by him and being personally known to me and by me duly sworn, duly proves the execution of said contract for the purposes therein expressed as to each one of the parties thereto.

"Witness my hand and official seal this.....day of ..... 189 .

"....., *Notary Public.*

"STATE OF ....., } *ss.:*
..... County, }

"I, ....., Notary Public, do certify that ....., the subscribing witness to the signatures contained in contract hereto attached, to convey lands to the ..... ..... Railroad, is genuine, and was made by him as witness to the signatures of parties named herein.

"Witness my hand and official seal, this ..... day of ....., 189 .

"....., *Notary Public."*

Prompt settlements should generally be made with parties claiming remuneration for so-called damages, as while it is better to allow a few cases to appear neglected, it is generally cheaper to the company to compromise the matter than to take chances with a jury. As the location progresses, the agent should of course secure the signatures of as many property owners as possible, on each line run. As soon as most of the signatures have been secured, the work of securing deeds from those who signed the right of way agreement should be vigorously prosecuted, and every effort made to settle the cases. A good many of the land owners will regret having agreed to give the right of way, and will try to get out of it by claiming various verbal conditions and agreements entered into with the right of way agent, for which reason, if for no other, the same man who secured the signatures to the agreement, should be the one to take the deeds. He is then prepared to deal intelligently with any land owner who may attempt to plead such conditions. Where parties demur about making deeds in accordance with their agreement, the company should stand firmly on its rights and fight it out in court. One thing, however, the author would especially recommend, and this is that everything connected with the right of way be kept as long as possible out of the lawyers' hands; any one who has had experience with lawyers in such matters will appreciate this remark. The following is a form of right of way deed which has been approved as good by several prominent railroad lawyers, and it appears to cover all the points likely to arise. The plat to be attached to the deed (see Fig. 2, Plate LXXVII), should not be made wider than the deed, and should always be noted in the deed as being part thereof. (Description in this form applies to property of heirs of John Clement. See Figs. 1 and 2, Plate LXXVII.)

"THIS INDENTURE, made this ..... day of ....., in the year eighteen hundred and ....., between ....., ..... and ..... his wife, of the County of ....., of the State of ....., parties of the first part, and the ..... Railroad Company, a corporation created by and existing under the laws of the State of ....., party of the second part, WITNESSETH, That for and in consideration of the sum of ..... dollars, to the parties of the first part, in hand paid by the party of the second part, the receipt whereof is hereby acknowledged, the said parties of the first part have bargained and sold, aliened, transferred,

granted and conveyed, and do hereby bargain and sell, alien, transfer, grant and convey unto the said party of the second part and its assigns and successors forever, with general warranty, the following property, to wit: A certain piece or parcel of land, situate, lying and being in Davie County, State of North Carolina, on the line of the said NORTH CAROLINA MIDLAND RAILROAD, containing four and six-tenths acres, more or less, and described as follows:

"Beginning at or near Station 1349 + 50, of the center line of the North Carolina Midland Railroad, on boundary line between said heirs of John Clement and Giles Howard; thence along said named boundary line, due north, to a point 50 feet distant from, measured at right angles to said center line; thence in a southwesterly direction, parallel to said center line, a distance of 1 345 feet, more or less, to a point opposite Station 1362+25; thence in a northwesterly direction, at right angles to said center line, to a point 125 feet distant from, measured at right angles to, said center line, thence south 20 degrees 5 minutes west, parallel to said center line, a distance of 140 feet, more or less, to a point on boundary line between said heirs of John Clement and T. W. Rich; thence south 2 degrees west, along said last named boundary line and boundary line between said heirs of John Clement and Ferris Clement, Troy Clement, and John Malone, crossing said center line at or near Station 1367+52, a distance of 550 feet, more or less, to a point 50 feet distant from, measured at right angles to said center line; thence in a northeasterly direction, parallel to said center line a distance of 1 880 feet, more or less, to a point on first-named boundary line; thence due north, along said first-named boundary line, to point of beginning, it being a piece or parcel of land, through the property of said heirs of John Clement, as will be more particularly shown by reference to attached plat, which is made part of this deed. To have and to hold the said piece or parcel of land to the only proper use and behoof of the said North Carolina Midland Railroad Company, and its assigns and successors forever.

"IN WITNESS WHEREOF, the said..... and.....his wife, hereunto set their hands and affixed their seals, this day, and year first above written.

"(Signed) ..... [SEAL.]
( " ) ..... [ " ]

"WITNESS: (Signed) .....

---

"STATE OF..... } ss.:
.....County, }

"I, ....., Clerk of the.....
.....Court, do hereby certify that.....
.....and..... his wife, appeared

before me this day and acknowledged the due execution of the annexed deed of.....and the said..... .....being by me privately examined, separate and apart from her said husband, touching her voluntary execution of the same, doth state that she signed the same freely and voluntarily, without fear or compulsion of her said husband or any other person, and that she doth still voluntarily assent thereto.

"Let the same, with this certificate, be registered.

"Witness my hand and official seal, this.....day of.....189 .

.....

"Clerk.....Court.

---

"STATE OF..... } ss.:
.....County, }

"I, ....., Justice of the Peace, do hereby certify that..... .....and ....., his wife, personally appeared before me this day and acknowledged the due execution of the within deed of.....; and the said..... .....being by me privately examined, separate and apart from her said husband, touching her voluntary execution of the same, doth state that she signed the same freely and voluntarily, without fear or compulsion of her husband or any other person, and that she doth still voluntarily assent thereto.

"Witness my hand and private seal, this.....day of .....189 .

"....., J. P. [SEAL.]

---

"STATE OF..... } ss.:
..... County, }

"The foregoing certificate of.....a Justice of the Peace of..... .....County, is adjudged to be in due form and according to law. Therefore let the same, with this certificate, be registered.

"This.....day of....., 189 .

.....

"Clerk.....Court."

---

All deeds should be made up in the Chief Engineer's office, and not one should be sent out without being numbered and charged to the person to whom sent for attention. These charges should be made in a book in which sufficient space should be allotted to each deed, to allow a full summary of the case from the first move in it until its final settlement. This record should show the name of the railroad, name of the party to make deed, number of acres taken, consideration, and when

and to whom sent. A careful brief of all correspondence about each case should also be made a part of the record, and a thorough register, carefully kept as indicated, will save much time and labor. In settling for right of way, it is often the case that a much better settlement can be effected if the money is in hand to be paid as soon as the amount is agreed on; for this purpose a sufficient amount should always be in hands of the Chief Engineer, to be disbursed as he may find necessary. When this money is delivered to the Chief Engineer, he can receipt a regular voucher for the same, the wording of which should state that the amount thus advanced is to be paid for right of way expenses and accounted for by sub-vouchers to be receipted by land owners, the same to be properly approved and turned in to the Auditor, who will make the proper credit; therefore when payments are made for right of way or damages, a receipt on a proper voucher should be taken for the amount paid, as well as taking the signature to the deed. A form for a voucher, as follows, will be found to cover most of the points likely to come up afterward:

"For land in.....County, State of.....,
.....acres, as per deed of.....189 ,
from....., to the.....
.....Railroad Company, and for all damages of whatsoever nature, to contiguous lands, growing crops, by reason of borrow pits, waste banks, change of roads, streams, ditches, etc., that may have occurred or that may occur by reason of construction and operation of said.....Railroad.

"No land should ever be paid for until the title for it has been carefully examined by the company's attorney, and a certificate received from him that title is absolutely valid. This certificate, with abstract of title, should be filed with deed to which it pertains."

To cope successfully with matters pertaining to settlement of right of way, a man should have some special fitness for the work. Ordinarily the man selected is one well known throughout the section in which he will be at work, and generally such a man is either a politician or a lawyer. In rare cases such men are satisfactory, but generally they are unbusinesslike, careless, and apt to neglect points which they may consider small and unimportant, but which may, years afterward, be the very ones for which some scheming lawyer is looking. The author has always thought that a good level-headed trader and business man, one who is incorruptible (if such a man can be found), would be a far better man for right of way work than one whose principal recommendation is his acquaintance with the people. It is often the case that individuals granting a right of way desire a permit from the company allowing

them to cultivate the land on the right of way and up to the edges of the cuts and fills until such lands are required for the use of the company. There is generally no objection to granting this permission, and a form as follows is suggested as one fully meeting the requirements of the land owner and not binding the company to anything.

"..... RAILROAD COMPANY."

"I HEREBY AGREE for the ..... Railroad Company, that ....., may have the privilege of cultivating so much of the land deeded by him to the said Railroad Company, as is not now occupied by its cuts and fills and other improvements, so long as said Railroad Company may not require such lands for its purposes.

"..... Railroad Company.

"By .....

"Chief Engineer.

"Given this..... day of ..... 189 ."

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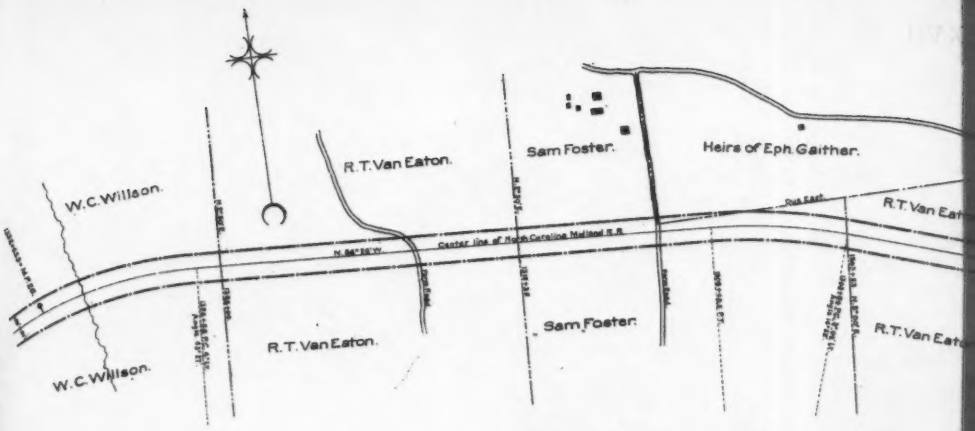
The making of right of way maps for permanent record is a matter that should receive the most careful attention. The first set made up should be used as progress maps on which the date of each settlement, as made, should be entered; and as rapidly as possible, maps showing the alignment, grade, width of right of way, etc., should be finished up on tracing cloth in mile sections, and on the scale of 1 inch to 200 feet, as shown in Fig. 2. The trouble with the generality of right of way maps is that they contain too much that is useless, and too little that is useful, but it is believed that the information given in Fig. 2, is all that an engineer will ever require in such maps; and when the State law requires the filing of right of way maps in the court houses of counties through which the line passes, this will generally meet all requirements. In this connection a satisfactory and economical permanent record for the court can be made by blue-printing the tracings on linaura or prepared blue-print cloth. In this way the labor and expense of making additional maps is saved, and one may be sure he has exact duplicates without checking them over.

As the subject of right of way for railroads is one that will every year become more important, and one with which almost every engineer will at some time have something to do, the author hopes that the Members will discuss this paper fully and give their views, pointing out any defects that may exist in the methods proposed, in order that others may profit by their experience.

## DISCUSSION.

ROBERT L. HARRIS, M. Am. Soc. C. E.—This is a subject of importance, which I am pleased that Mr. Hall has brought to the notice of our society, and I indorse his paper. The subject is one with which I have had much to do in various States and in Canada. My experience has been that, whenever the obtaining of the right of way has been made one of the duties of the Chief Engineer, there has been little, if any, unnecessary trouble; everything concerning it has gone along systematically and pleasantly. Whenever, on the contrary, the matter has been in charge of a man not under the direction of the Chief Engineer, there have been difficulties and trouble. All the data must be obtained from the office of the engineer, and the subject is far more distracting to his attention, and there is more likelihood of error if, in the multiplicity of details and new business attaching to the earlier months of the railway, he be interrupted at any and all times by the necessary queries and conferences about right of way matters which he, when knowing all about, would naturally settle in proper season. Moreover, the education of the engineer being to exactitude, his future reputation is at stake, right of way matters being those of permanent record. Although the original details of extra widths for deep cuts, high banks, borrow pits, spoil banks, extra tracks, buildings, etc., may be well worked up, yet exigencies will occur during construction, where an addition here and there will be of great value to the railway company. If the right of way is in the engineer's charge, this can be done promptly, pleasantly and without talk or extra stir.

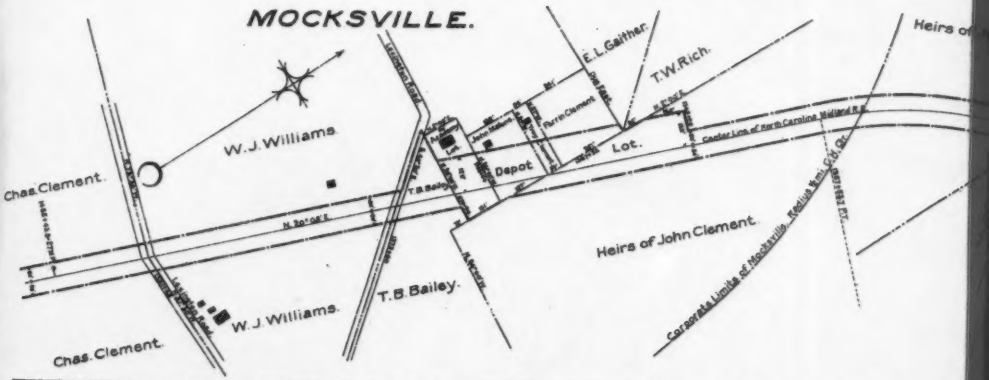
Most railway engineers have, from necessity, migratory habits; yet the right of way agent usually takes his flight earlier in the fall, and then uncomfortable or perplexing questions are left for the engineer, and there is a mass of details, papers and correspondence to be searched to settle such. The engineer, being the first on the ground, it is to the interest of himself and his parties, as well as for the pleasure and the advantage of the company, that friendly relations be cultivated with people along the route. The engineer is naturally invited to the homes of land-owners, and for the time-being is one with them; consequently it is a source of chagrin to him and detrimental to the interests of the company if the first officer to follow is not of the right stripe, is a schemer, unfaithful, or even disagreeable. The matter is best settled by having the right of way obtained through the Chief Engineer by agents who appreciate his position, act under his direction, and report only to him. Mr. Hall well says the agent should be "an honest, competent, business man." Among the qualities necessary I would place first, truthfulness; there should be no misrepresentation; "fraud




# North Carolina Midl

Located Line Sta. 1278 to Sta. 1486.
Davie County, N.C.

Surveyed in 1889 by M.O. Hankins, D.E.



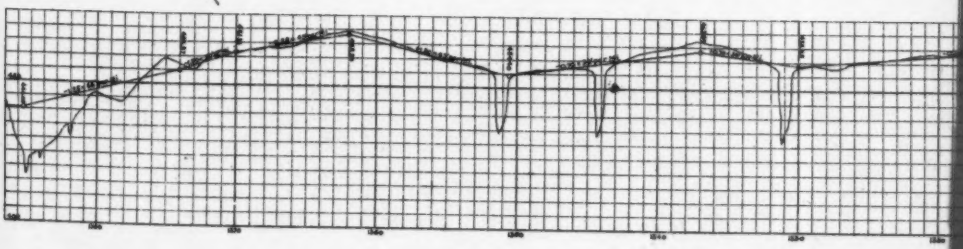
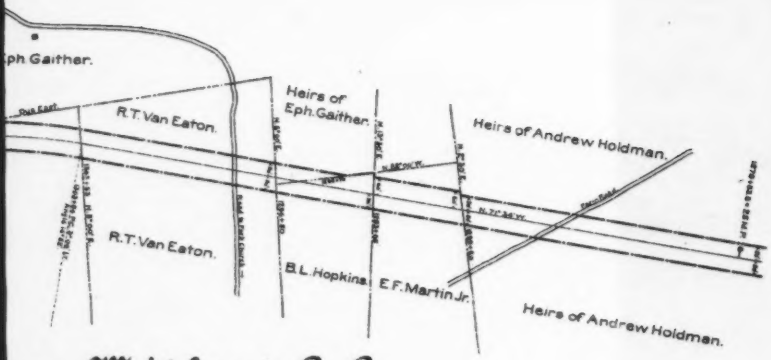



FIG. I.

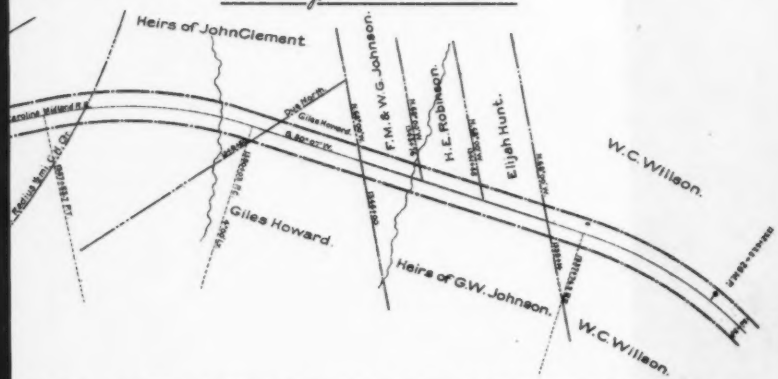


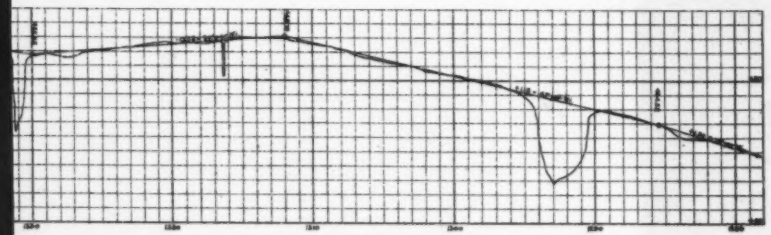

# na Midland R.R.

e Sta. 1278 to Sta. 1486.
e County, N.C.

1889 by M.O. Hankins, D.E.

A. Monument, President
Channing W. Bolton, Chief Engineer



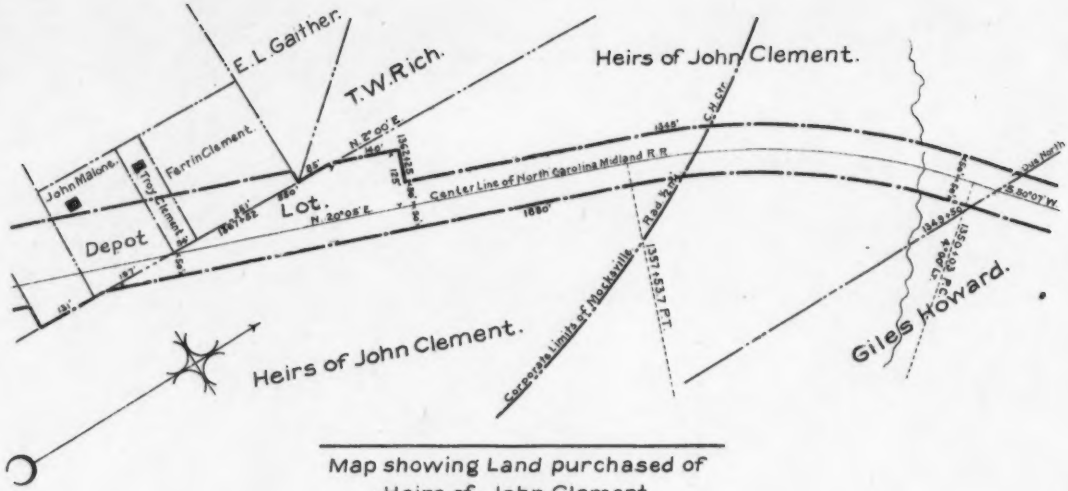



FIG. 2.

Map showing Land purchased of
Heirs of John Clement
by the
North Carolina Midland R.R.
in Davie Co, N.C.

Attached to Deed from Heirs of John Clement to the North Carolina Midland R.R. dated Feby. 5. 1891.

PLATE LXXVII.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXV. No 501.
HALL ON RIGHT OF WAY.

vitiates a contract." Upon one road of which I was Chief Engineer, the right of way agent acted independently, and he boasted to me that he would obtain deeds for the right of way of over 50 miles of settled country for "a dollar a farm." He succeeded (he thought), but I have been informed that a half dozen years later, when the land had become valuable, some dissatisfied farmers brought suit on the ground of misrepresentation, and the right of way for the entire length of road had to be purchased at a greatly increased valuation.

When a railway is first proposed liberal grants can be readily obtained; this is the time for them to be secured. Upon a road of which I was engineer, in a well-settled, fruitful, farming region, not so far distant as Chicago, not barren of railroads, we would not accept for local station grounds a donation of less than 3 000 feet long by 250 feet wide. There was no difficulty in obtaining such when it became known that this was the standard, and at some points there was competition from the neighbors for the privilege.

In regard to the paragraph on the first page of the paper, a circumstance interesting to me occurred three or four years ago, which shows the desirability of full transit notes even in a wild country. In the company of a friend I called at St. Paul, at the offices of one of the largest railways in the Northwest. Upon being introduced to the engineer, he expressed pleasure, and said, "Your name is familiar;" he then took from the upper shelf of a large book-case a package of old note-books, handed me one, with the question: "Do you recognize that?" It was an old, worn transit-book of mine of 1858–59, when the country to the north was a wilderness and land of no money value. "That book, sir, has saved the company many thousands of dollars, the few local notes then to be had were taken with such care; and this is one of our books of reference in land and other matters."

Commenting briefly on other portions of the paper, should not the paragraph on the third page of the paper, which provides that, "So soon as the railroad is constructed a proper deed for a right of way of prescribed width shall be given," read, "so soon as the road is located?"

Naturally, in many countries, and even for right of way purposes, several lines will be run, but it is well if the Chief Engineer does not receive (these) instructions, for then the object he would attain is pretty sure to leak through others.

I am pleased that Mr. Hall makes the distinction between right of way compensation, and "so-called damages." These last should be promptly settled, whether they are from the destruction of a line of corn-stalks, the mere ravishing of a melon patch during the survey, or the greater devastation caused by the construction of the railway.

Mr. Hall says: "As the track laying progresses, the agent should, of course, receive the signatures of as many property-owners as possible

on each line run." I would suggest that this read, "as the location of the line progresses."

I agree with the statement that it is desirable to keep right of way matters as long as possible out of the lawyers' hands in the way of quarrels. This is correct; but the engineer should have the privilege of consulting freely with a good lawyer, especially at first, as the laws of the various States vary in the matter of title and conveyancing as well as in details. I may add in this connection, that in some States only right of way can be secured for a railway, and if not so used within certain periods of time, the lands revert to the previous owner.

It is generally better to describe from the center line of railroads, as has Mr. Hall, than from other boundaries, as the line in most of the States must be filed in the offices of the county clerks, and a base is thus fixed.

I do not agree with Mr. Hall in the statement that "there is generally no objection to granting permission to cultivate land on the right of way and up to the edges of cuts and fills until such lands are required." Harsh though it may seem to prevent adjoining and original owners from utilizing what is seemingly waste land; yet when a road is once built and in operation, the safety of the public is paramount. While the original engineers are on duty, and while the boundaries of the right of way are fresh, the lines of the land obtained by the company should be fenced off, and thereafter kept clean as well as clearly defined.

In conclusion, let us hope Mr. Hall's paper may tend to this matter being always placed in the hands of the engineer, and we should thank him for his effort in that direction.

P. F. BRENDLINGER, M. Am. Soc. C. E.—I just received my copy of this paper to-day, for which I am very sorry. It is a subject I have a great deal to do with, and it covers a very large field. I differ very radically with Mr. Hall in this right of way matter, and I propose to give my views when my notes are sent to me for correction.

Mr. Hall says, in the latter part of his paper that he hopes the members will discuss this paper fully. He has merely scratched the surface of the whole matter, and, as I said, it is a tremendous field—a field so large that I cannot commence to discuss it to-night. I saw a little illustration the other night in the Madison Square Theatre, in the play called "Alabama," which you have probably seen, of the trouble they had to get the right of way in the South. I will not attempt to discuss the subject this evening,

C. J. BATES, M. Am. Soc. C. E.—It is nearly twenty years since I have had anything to do with this subject, and I suppose that I am about as rusty as some of the railroads are. I located a great deal of the Baltimore and Ohio's Chicago line, and it was Mr. Garrett's policy always to buy his right of way in order to have a fee. He said he objected to possessing any right of way that would at any time revert. For this

reason we were occasionally delayed for some time. There was at one time a year's delay and an additional cost of $100 000 to avoid condemnation proceedings. He owned his line throughout, and, of course, his deeds were taken as Mr. Hall mentions, and everything was kept in perfect shape.

One thing I did not understand. Mr. Hall, in giving his form of deed, does not discriminate, does not show whether, when he takes the property in the shape that he gives, it would not revert in case the road abandons it, as is the case with all railroad property. Could not this be discriminated in any way?

E. P. NORTH, Director Am. Soc. C. E.—Does not that depend upon the laws of the State?

Mr. BATES.—I was speaking more particularly of Ohio. The right of way obtained by condemnation will, if abandoned by the railroad company, revert to the owners, but the right of way bought, as was all the right of way by my employers, will never revert.

Mr. NORTH.—I think, in some States, as in Connecticut, it is impossible for the railroad company to buy anything more than an easement.

Mr. HARRIS.—This is true, and the land will revert if not used for railway purposes.

CHARLES B. BRUSH, Director Am. Soc. C. E.—In New Jersey the condemnation proceedings extend to the right of way, not to the fee. The fee can only be obtained by agreement.

A statement is made in this paper which reads as follows: "A satisfactory and economical permanent record for the court can be made by blue printing the tracings on linaura or prepared blue-print cloth." These preparations are not satisfactory for permanent records. I think a mistake is made in registry offices when they accept such prints for records. Records of permanent value like this should be made by hand rather than by blue prints.

The right of way agreement, given in the paper, is a better thing for the railroad company than it is for the property owner. It gives the railroad company permission to locate its road where it pleases. While this may be possible in some parts of the country, it is not possible in this locality. When an owner gives to a railroad company "a sufficient deed to so much of his lands as shall be included between lines * * * feet from and parallel to the center line of the road as it may be finally located by the company," he simply gives the company a roving commission to take possession of his farm. In many sections it would be impracticable to obtain such a deed.

I think it is an improper description to locate a piece of land from the center line of the tracks, because these are shifted from time to time. When a railroad goes through a farm, for the safety of the railroad people and for the safety of the owner, the point where the road crosses the boundaries should be located from given land marks. I think the ten-

dency of the paper is to look at this matter more from the standpoint of the railroad than from the standpoint of the property owners. I believe the only way that a satisfactory location can be made, where property is taken for public purposes, similar to this, is to make the location and arrangement with the owners in such a way as will be mutually satisfactory to both. I do not believe that can be done unless the agreement is definite. Generally it will be found that, unless the farms are large, it is better to buy a farm outright, or buy a portion of it rather than it is to go into detailed descriptions for buying strips. Where railroads are necessary for the development of a given locality the right of way may be obtained easier than in this section. Any one attempting to proceed on the lines laid down in this paper in this portion of the country will almost certainly fail.

The question of the right of way being referred to the Chief Engineer is very important. I think it should be so done. On the other hand I think rather too much is made of the lawyer side of this question. I am very glad to have a competent lawyer work in connection with me. If the lawyer is not properly fitted for that kind of work he would not be of the same advantage that he would be otherwise; but I think it is a serious thing for engineers to go too far outside of their lines, where the question of legal and vested rights are concerned. It is right and proper that the lawyer should understand that his part of the work should be confined within certain limits; the same is true of the engineer.

J. Foster Crowell, M. Am. Soc. C. E.—I am much more inclined to take the view that Mr. Brush has taken than those of the author of the paper and the first gentleman (Mr. Harris) who discussed it takes. The difficult parts of questions of titles seem to me to have very little to do with engineering requirements, and sooner or later legal knowledge is necessary; if not secured at the outset it will land the company in misunderstanding later.

The author of the paper has not in his mind, I think, a real estate lawyer, but rather the employment of a lawyer as a right of way agent. It is absolutely necessary, I should say, that the Chief Engineer should have the direction as to what property is needed. He should also have matters connected with the preliminary negotiations sufficiently under his control to secure the interests of the company as regards its relation to the adjoining owners. Often a right of way agent has too much latitude given him, and he embarrasses the company with his heedlessness of requirements. I have in mind a very zealous man in this business, who was always looking after his reputation as a buyer, and I have known him to sacrifice the interests of the company in the future for the sake of keeping down the schedule of first cost of right of way. In one case, in a farming district, in order to accomplish this, he had given so many cattle-pass and bridge crossing privileges to the owners that while he had a small right of way account he had added an average of several

thousand dollars a mile which the construction department had to supply. In most cases the conditions were not required by the owner, but were offered by the right of way agent in lieu of cash. The resulting loss to the company as appeared afterwards in the construction account was very large in the aggregate. It goes without saying that these matters should be under the control of the Chief Engineer. When that is done, when the basis of these negotiations is settled in each case, the business should be turned over to the legal representative of the company as a matter of course and necessity.

Mr. Hall might find in some new country a scope for the intervention of the engineer which he thinks necessary, but in a settled country the engineer, if attending to the right of way matters, would have very little time for the construction of the road. He has in mind an engineer with a small staff, which is a very different state of affairs from that of one of our great railway companies passing through a settled country, where the real estate department takes an immense amount of time. Any one knowing of the real estate department of the Pennsylvania Railway, for instance, will see that this is a matter that the engineer engaged in construction or location cannot possibly attend to in a satisfactory manner to his company.

A MEMBER.—Circumstances in different States seem to differ widely. I have in my hand a slip of paper, giving a very recent decision by Judge Daniels, of the General Term of the Supreme Court. Several years ago the railroad company with which I have been connected, purchased by agreement with the owner a piece of property in this city. That property, with other property surrounding it, has since been designated by the City Commissioners as a public park, and for various reasons the construction on the part of the railway has been delayed, and now the company are anxious to construct on the part that has been condemned by the Park Commissioners, and find themselves debarred from it.

Mr. NORTH.—I think all agree that an engineer who starts out to acquire a right of way unaided by legal advice would be as apt to come to grief as the lawyer would who started out to build a railroad without consulting an engineer. As far as I know, where a road employs a great legal light and sends him out to contract for right of way—not reporting to the Chief Engineer—the road is liable to come very much to grief in its right of way matters. It seems to me it has worked better in several cases that the lawyer should be employed by the Chief Engineer and report to him or to the Assistant Engineer in charge of the work. By this means he is put into immediate communication with the man who knows the line the best; he is prevented from making any foolish contracts. In addition, you can generally rely on the engineer being honest; you cannot rely entirely on the lawyer, because he is apt to have a side issue with the people of the country, and does not devote himself so fully to the interests of the company as the engineer does, who has no friends in that country to reward or enemies to punish.

I want to emphasize what Mr. Brush says about the contract for right of way. Mr. Hall says you must have an honest man. I don't understand you can get a man who is honest on one side and dishonest on the other.

Where land is worth a great deal it is best both for the railroad company and the land holder that the points should be rigorously described, but in wild land I do not think it is necessary or desirable. It does no damage to a land holder, with five or ten dollar an acre land, to describe the right of way by its distance from the center line. If such land ultimately gets a value of $500 or $600 an acre, it is probably the railroad which has given that value to it. The company, while it does not swindle the land holder, should prevent as far as possible any swindling suits against itself. If an effort is made to locate from section corners, you are liable to find that a mistake has been made by the engineer and surveyor, and you have a great deal of trouble; but by referring the boundaries of the right of way to the center line, there is no chance for any trouble that I have ever known. The average corner in lands of low value is often undetermined and its true position is not established until the value of the surrounding land justifies a suit.

CHARLES E. EMERY, M. Am. Soc. C. E.—My experience in this line dates back some thirty-three years, to a time when I was a student in an engineering office in Central New York, where railroads were being built under the direction of Marvin Porter, Esq., and when E. S. Philbrick, M. Am. Soc. C. E., was his assistant engineer. Afterwards I was a student in a real estate law office, and I must say that the methods which were then employed in Central New York were nearer those stated by Mr. Brush than those referred to by Mr. Hall. It is true, as has been said, that the methods of procedure must be different in different parts of the country. In sections comparatively undeveloped it may be practicable for an engineer to take blank contracts with him, fill them up and have them signed as the location progresses; but in the older States, where the farms are comparatively small and every foot of land is known to the owner and in some sense valued, it is absolutely necessary to conduct the whole matter from the start carefully, in accordance with the business methods of the particular locality. My recollection is that at the time referred to the matter was in charge of the attorney of the company and of the Chief Engineer, under the general direction of the president; and that after the names of the towns to be reached had been fixed, the Chief Engineer usually laid out the line where he desired it, and a local attorney was employed in each county to deal directly with the land owners, secure the execution of the necessary conveyances, attend to the recording of the same and the filing of necessary maps, and in general to smooth the way in all directions, in conference with the engineer and other executive officers. The employment of local talent had the effect to make the road popular,

and a person who knew the individuals could deal much better with their personal peculiarities. Slight changes desired here and there were generally adjusted by conference. The counsel of the company arranged that all conveyances were in satisfactory form before approving the payments, and on the whole the business was conducted in customary business ways, differing, as will be seen, very little from that in which any private individual would arrange for the purchase and secure the transfer of a single piece of property. Obstinate men were found, of course, but as the business was conducted so as not to cause public disapproval, the more difficult cases were generally solved with comparatively little difficulty.

GEORGE R. HARDY, M. Am. Soc. C. E.—I want to call attention to one feature of the paper under consideration. The scale mentioned as desirable for plans to be filed is 200 feet to the inch, and it seems to me that in most of the east, at least east of Chicago, if the land is of any value at all it is relatively too small a scale. The desirability of describing the property in the manner which is suggested, at distances from a center line, is manifest, but a very short description, avoiding going into inside meets and points, is necessary in order to locate city lands. That is rendered necessary in places where land is bought and sold by the foot; with some lawyers I have found that there was no other way of satisfying a railroad form. The best results were found by describing the land bought and required by the railroad company, but as soon as one goes outside of villages it is sufficient to describe the land by the distances from the center line, and in no case have I found it satisfactory to describe the distance from a center line which has not been located; the result in that case is too indefinite to have a permanent value. If the railroad company has located its line and established it, the line should be so located by reference points that it can afterwards be revived. I have had a great deal of business in the course of reviving an old location, and the difficulties have been in obtaining property that is described "as now staked out." The location should be well defined and at tangent points some permanent record may be placed, or if there is any masonry in the construction at that place, getting offsets from the center line, then the widths at each side can be revived at any time. But it is necessary in all such cases that the right of way maps should be of such a capacity as to admit of writing the exact widths without crowding the plan at all. Also to be able to locate the masonry features of the road by distances and offsets from the center line, such as the bridges, cattle guards and culverts; this is necessary, and once having these located as above, a great deal of the difficulty of reviving the old location is eliminated.

Mr. BRUSH.—If the center line is well defined and made a matter of permanent record, I do not think it necessary to go into the question of meets and bounds. I referred rather to cases where the location of the center line was indefinite.

Mr. CROWELL.—It would be impossible to lay down hard and fast rules that would apply universally. In new countries, where securing the right of way is a necessary preliminary to starting the enterprise, it is often necessary to obtain a release first of all, the release having a binding effect on the owner; the deeds are afterwards prepared in conformity with it, but with a description resulting from the final surveys. It is quite sufficient for such purposes to define in the release a "strip of land" which shall "conform to the line as it may be located." But in thickly settled portions of the country, where land is valuable and all taken up, there is hardly ever a necessity for this haste, and negotiations can be begun on a basis determined by actual location and determination of grade. I think we are rather talking around the question in going so much into details, because they would vary in nearly every case; what would be proper in one case would not be necessary in another. I think Mr. North, in his remarks as to the advisability of a little looseness, does not really conserve the interests of the railroad company; it might possibly find itself in trouble on account of the looseness of the description; where possible, it is very much better to recite in the deed the connection between established points and the center line, but the description should be built upon the center line invariably.

Mr. BATES.—It may be interesting, as a matter of precedent, to say that, in the case I speak of, all employees of the company were absolutely forbidden to make any promises to the land owners; and in many cases, where an end of a farm was cut off, that end was purchased from the farmer and afterwards sold back to him at a reduced rate, the difference in cost being in favor of the railroad.

Mr. HARRIS.—In the more unsettled parts of the country the center line is fixed, it is recorded in the county clerk's office, and is readily retraced at any time, so that, except in very valuable lands, it is generally most convenient to describe by using the center line.

Mr. WILLIAM P. SHINN, Past President Am. Soc. C. E.—This paper of Mr. Hall's is one of very considerable and rapidly increasing importance. The great increase in value of property which has been brought about by the construction of railroads has become a source of considerable expense to the railroad companies, because when they were constructed it was not thought necessary to properly secure the right of way. There are some points that have occurred to me as quite important that have not been mentioned by Mr. Hall. Mr. Hall refers to the fact that legal decisions have been made to the effect that a railroad company cannot acquire right to land by occupation. It was thought for many years that the law of limitation, which operates against private claimants of land, would also operate against the previous owners of land occupied by railroad companies. I think the first decision upon that point was made by the Supreme Court of Pennsylvania, in which

they decided that inasmuch as private property taken by railroads is "private property taken for public use," and as the Constitution provided that "private property should not be taken for public use without compensation," that the property could not be considered as taken until the compensation was made, and so, in fact, although the property had been occupied by the railroad company for a period longer than would have sufficed to have given a private party in possession the ownership of the land, the court decided that there was no ownership by possession.

Mr. Hall refers to the importance of making right of way maps and having them recorded, and that the originals should be returned and filed in the Chief Engineer's office. We all know what is meant by "filing" a plan. It means to put it in some drawer or closet, and when it is wanted the chances are against its being found. Instead of being satisfied with merely "filing" the plans, the proper course to take, in my opinion, is to make these plans on sheets which shall be bound in books; those books are not easily mislaid. In the last four railroads that I have had charge of (in neither of which had any right of way maps been preserved in that way) I had maps of the right of way made in this manner. Each county was made the contents of a book; the first page of a book—the pages being about 20 x 40 inches in size—contained a map of the alignment and property lines in a general way, within the county, drawn to as large a scale as the size of the sheet will permit. Then followed on the next page the alignment and right of way lines in the first township passed through in that county; then on successive pages the right of way maps prepared on a large scale, giving one or more on the page, according to the length of line in land owned by each person. The maps of the county being completed, were bound together, paged and lettered on the outside so as to be easily referred to. In addition to those maps I had also a record book in which the descriptive parts of the deed, or condemnation paper, or whatever title the company had, were entered plainly, being copied verbatim, with a reference to the book and page of the right of way map. This book, being indexed, furnished practically an index for both books, and in that case any particular right of way and the character of the title held by the company could be ascertained in a very short time. If that were done immediately after a railroad was built, or while it was in process of construction, it would be seen at once whether the title was positive or defective. In making up these maps and records on the roads to which I refer, we discovered in quite a number of cases where it was supposed the company had the right of way, that there was no complete title.

There is another subject which is referred to by Mr. Hall in his paper, that is, the importance of having a good business man to secure the right of way. While it is proper for the engineer to locate it and mark it out upon the ground, as a general thing the engineer is not the best party to make the bargain for securing the title; but one difficulty

with the average right of way agent is that he expects to be held responsible for the sum total in dollars and cents only of the cost of securing the right of way, and if he comes to an actual case in which it will cost $1 000 for a road across the track, or a cattle pass for the payment of $50 or $100 in cash for the right of way, as the expenses of road or cattle pass go into the construction account, they will be allowed to outweigh in his mind the advantage of securing the right of way for $50 or $100 in cash, so that it is true that the right of way agent should not be allowed to make any bargain without the approval of some officer of the company. Mr. Hall suggests paying the money into the hands of the Chief Engineer for the purpose of making some settlements. In that I do not agree with him. I think the Chief Engineer has enough to do without handling money or making settlements, but he can make a contract in some cases and he should make his proper voucher and certify it to the proper disbursing officer of the company.

There is one thing more: not only is it important to secure the right of way by deed or other form of title, but it is especially important to secure the exact location of that right of way. The importance of that matter has been brought very strongly to my mind within the past two weeks, in which I have been called upon to give some information and probably to testify in court, as to how the center line of the railroad that I was on and engaged in the construction of forty-one years ago was located with reference to the tracks. The title to the right of way in that case is all right, but the question is, where is the right of way? A man has built a stone wall in such a position that the railroad company claims it encroaches upon the right of way, and they wish him to take back his stone wall, but the man replies: "My stone wall is on my own land; I have such and such boundaries and my wall is on my land, and you take your old railroad and put it on your own land." In that case there is no possibility of absolutely establishing the exact location of that original center line, and that causes me to remark that as soon as the preliminary location of a road is made, every point of change in the alignment should be located by good reference marks and on long tangents (such as we have on many western roads); points in the tangents, probably every half mile, ought to be so located, when the road is built; before these reference marks perish, good substantial monuments should be put in the road-bed, marking that center line. We are in the habit of getting up monuments marking the lines of much less important property than that, and yet I presume that not more than one road in fifty of the railroads of the United States has any permanent marking of its center line.

Robert Moore, M. Am. Soc. C. E.—I would like to add my testimony in confirmation of what Mr. Shinn has said as to the great value of preserving papers. In my experience there is no way of doing this except to bind them. As a rule, the unbound sheet disappears in a very

few years, and if, as in the ordinary custom, the engineer himself is dismissed as soon as the road is opened, it is very sure that his loose sheets will be scattered in a very short time. Every one should make it a rule to see that they are permanently bound so that they can be easily preserved.

GEORGE B. NICHOLSON, M. Am. Soc. C. E.—As to the cost of getting right of way after the track is laid, I can cite an instance in my observation. I had in my possession a deed very carelessly made out by a right of way agent, who obtained the right of way some years since through a farm by a deed containing a condition which required the railroad company to keep all drainage to one side of the track, although naturally it should cross it. The land owner did not ask for the condition to be fulfilled until fifteen years had elapsed. A survey revealed the fact that it would cost about $3 000, or as much as the farm was worth, to keep the drainage from crossing the track. The land owner was then offered a cash consideration of $300 to take care of the rain-fall himself, which offer was accepted with alacrity, and for five years the water has continued to flow through the box culverts under the road-bed.

I have in my possession the deeds of one of the first railroads built in the south, which deeds date back to the year 1835. I suppose the projectors and builders of this road had had no experience in railroading, and their ideas of how they would operate it were somewhat vague. They must have thought that it would be conducted after the manner of a canal; that is, that the company would furnish the railroad and the patrons the cars, for the consideration in one deed for the right of way was that the railroad company was to provide a "burden" car whenever required by the grantor or his successors and assigns. One company succeeded another as in the usual fortunes of railroads, but the "burden" car had never been furnished, and after the lapse of nearly fifty years the son of the grantor sued for the performance of contract and damage for past neglect. The decree, which was sustained by the Supreme Court of the State, awarded the plaintiff $15 000 for past damages, and enjoined that the company should provide the car for all future time whenever demanded. The $15 000 was not paid, as the road was sold at a receiver's sale shortly after the final decision, and the debt was thus wiped out; but the irksome stipulation of furnishing a car still continues in force.

With the object of avoiding the obnoxious condition, a survey was made for a new line around the farm, which was only half a mile wide along the track, but as it extended one mile on each side and as the original line had been well located on the best ground which could be found in a hilly country, the cost of building a new road was so great that the subject was dropped and the railroad company now furnishes the "burden" car.

I disagree with Mr. Shinn concerning the control the Chief Engineer

should have in purchasing the right of way. Of course he is a very busy man and cannot personally look after the details, but he should have the supervision of the right of way agents. If this has not been the case in the original construction, the engineer or his successor in charge of the finished road will have years of labor in eliminating the mistakes of right of way agents. I speak from severe experience.

In making out deeds I think the legal department and the engineering department should work together. It has been my fixed rule, no matter how simple the deed may be, to insist upon writing the description myself, and that the lawyer shall examine the deed, to certify to its correctness as a legal document. I have frequently to deal with trouble in right of way on account of the looseness with which descriptions in deeds have been drawn.

Mr. SHINN.—I wish to correct the impression of Mr. Nicholson that I mean to convey the idea that the right of way agents should not be subordinate to the Chief Engineer. I merely said the Chief Engineer should not have to attend to the business himself. I do not think the Chief Engineer should have the disbursement of the funds, but he should approve all contracts for right of way before they become binding.

FRED. BROOKS, M. Am. Soc. C. E.—In Massachusetts the Board of Railroad Commissioners has established rules in detail for the systematic mapping of railroad locations for record, in pursuance of Section 93 of Chapter 112 of the Public Statutes, which reads:

"The Board shall prescribe such rules as it may from time to time deem necessary in regard to the form in which all records of locations of railroads shall be made, the particulars to be contained therein and the manner in which such records shall be uniformly kept for preservation and convenient reference in the offices of the clerks of the several counties. No such record shall be filed until the Clerk of the Board certifies thereon that the same is prepared in conformity with the rules prescribed by the Board."

Mr. BRUSH.—The company with which I am connected does not accept any deed until the engineer and the counsel of the company have actually indorsed thereon the fact that they have approved the description and the form of the deed. This action has been taken during several years past and the result has been entirely satisfactory to the company.

JOHN F. WALLACE, M. Am. Soc. C. E.—Engineers engaged upon railroads will appreciate Mr. Hall's efforts to attract proper attention to this department of railroad work. During the rush of construction the first thing considered is, usually, how immediate possession of the right of way can be obtained, and it is seldom that care and attention is given to the matter of procuring the execution of the proper deeds and papers. This is a most prolific cause of trouble.

During the location and construction of a line of railroad built sev-

eral years since, of which the writer was Chief Engineer, the right of way agent reported to the Chief Engineer and followed the location party closely. Each night the agent was furnished with sketches showing the location of the line, and instructed as to what and how much variation from the located line should be mentioned in the right of way contract; also as to where under or over crossings could be provided, and any other special conditions which would enable him to act intelligently in making contracts. The right of way agent was instructed to close contracts with each landowner at first interview, if possible, if not to inform the landowner that condemnation proceedings would be immediately commenced. All right of way cases that could not be promptly settled were at once placed in the courts for adjustment. Upon completion of the road deeds were required and all titles perfected; when differences arose that could not be arranged suits were instituted to perfect title.

Upon the completion of construction, the right of way map should show all lands belonging to the railroad company, the location of monuments and the character of the title, also the names of previous owners. A record book should be kept in the office of the Chief Engineer containing an abstract of every deed, a description of the land, references to the right of way map, and all conditions mentioned in the deed or agreement.

During 1889 and 1890 the writer was connected with the construction of a railroad terminal into the City of Chicago. Our line was located approximately on existing maps and the securing of the right of way placed in the hands of a real estate agent, who acted as trustee for the different roads interested in the terminal. Before the public were aware of the construction of the road, over two-thirds of the right of way had been secured by deed. In all cases entire lots were purchased and parts not needed afterwards sold. After securing a city ordinance in which the route to be taken by the railroad was designated, all unsettled cases were placed in the courts and title secured by condemnation. The values placed by the courts upon the land taken were reasonable and fair, and generally within the amounts previously offered by our right of way agent.

The right of way agent should, in all cases, report to and be under the direction of the Chief Engineer. Trouble is often caused by the right of way agents agreeing to conditions and assuming obligations, which the engineer in charge of construction may find unwise or impossible to carry out. The result of this is litigation and the making of enemies among the future patrons of the road.

The writer, some ten years ago, had charge of the construction of a terminal line into a western city. The line was located for a distance of three miles along a river front between various industries and the river. In one case a large elevator had constructed a loading dock out

into the river and connected it with the main elevator by various carriers, in order to load and unload vessels at the dock. Our line was located between the dock and the elevator, and not being able to reach any agreement with the elevator company, condemnation proceedings were instituted. The railroad company filed plans showing how the railroad could be constructed and how the elevator carriers and connections could be re-arranged to admit of the joint use of the property by both parties, and requested the court to assess damages, if any, upon this basis. The elevator company endeavored to convince the court that, while the railroad had the right to condemn the fee to the land needed, the condemnation must be absolute and not partial. The object of this stand upon the part of the elevator company being to obtain a verdict for such excessive damages against the railroad company as to prevent the construction of the road, the elevator company being owned and controlled by a rival railroad company. The court held that the railroad company asking for the right of way could file plans and prove its intention to construct the road in accordance therewith by the testimony of its engineers; and that the court, to determine the amount of damage due the elevator company, should consider the effect upon the elevator company, of the construction of the railroad in accordance with said plans. This decision was afterwards affirmed by the Supreme Court of the State of Illinois. The same ruling has since governed where railroad companies have condemned their right of way through farm lands, and filed plans to provide for under and over farm crossings, in order to show a minimum damage to the property owner.

Annexed is a simple form of right of way agreement, which the writer has frequently used and found very satisfactory. Separate agreements are preferred with each landowner, as it is seldom that signatures to a general agreement can be obtained.

RIGHT OF WAY.

"IN CONSIDERATION of the benefits to be derived from the location and building of the....., and ONE DOLLAR to me in hand paid by said railroad company, the receipt whereof is hereby acknowledged, I do hereby grant and convey unto the said..... ..... the right of way for said railroad..... wide over or across the.....
.....
.....
.....
.....

"AND I PROMISE AND AGREE to make all proper and necessary deeds to convey in fee simple to said company, said right of way, as soon as said railroad is located on or across said above described lands or lots.
.....
.....
.....

"WITNESS my signature hereto, this.....day of ....., A. D. ..... ....."

H. V. HINCKLEY, M. Am. Soc. C. E., writes: A certain amount of system as to deeds and maps is both essential and economical. The following suggestion will show the system that I have used on the Santa Fé road for the past ten years as the result of previous experience. Deeds for all grounds except for a uniform width across a section or quarter section are made out in my office and sent usually to the right of way agent. Attached to each deed is a memorandum slip or tracer as follows:

Acres, 10.6..... At Garden City..... H. V. H.'s No. 1376
Price, $100..... Total, 1 060..... For Stock Yards..... By J. E. L..... Check E. N.....
Title O. K., Abstract 137..... Owner. P. Jones..... To C. B. K., 3/19..... 1887....
Sent O. K. to..... 188.... Abandoned for.....188....
..... .....

*TO THE PARTY NEGOTIATING:*

When deed is secured, or for any reason abandoned, fill the above blanks, note hereon any changes that have been made, sign on lower line, and send this memorandum promptly to—

A. A. ROBINSON,
*2d Vice President and General Manager,*
TOPEKA, KANSAS.

For H. V. HINCKLEY,
*Office Engineer.*

This tracer is copied with the deed in an impression book, and when the slip comes back to us the notation is promptly entered on the impression and may read as follows: "Sent O. K. to Treasurer 3-20-87," or "Abandoned for condemnation 3/20/87, all papers to law department." Each deed also has my number on its face, so that any error made in my office can be traced to the man who wrote the description and the man who checked it, and by these slips any lost deed can be traced to the loser.

The deed is sent by the right of way agent with the voucher to the treasurer. The treasurer gives the deed his consecutive number, and it then comes to the Chief Engineer's office for certification (on its back) and entries as follows:

In the right of way book A, B, C, or whichever book has the deeds of the line to which this deed pertains.

In the name index book.

In the numerical index book.

In the right of way map or station plot, correcting the same to date to correspond with the deed.

All deeds must be sent by the treasurer to the Chief Engineer when they come in. All deeds reaching the Chief Engineer must be promptly entered as above and returned to the Treasurer.

As to blue printing I cannot see how a road can afford to be without an apparatus for this purpose. We have four frames, 3 feet by 9 feet, capable of printing 5 000 yards per month, and we have run as high as 3 600. Also one frame, 4 feet by 5 feet, for old odd sized drawings. No drawings are now allowed to be made over 36 inches wide. A boy runs the four frames, and has a helper during times of construction.

## DEED RECORD BOOKS A. B. C., &c.

T 21 S. R. 13 E.

| TRACT. | DESCRIPTION. | GRANTOR AND DATES. | CONV. AND CONSID. | NUMBER. |
|---|---|---|---|---|
| N. E. ¼ of 34 | 50 feet each side of center line. Also, 50 feet Extra each side from station. 260 × 40 to station 280 × 16.<br><br>Printed alike on both sides. | John Smith *et al*, W. D. ex. 3/20/87. Rec. 3/21/87. | Warranty, 1 200.00 | 11348 |

NUMERICAL INDEX.

| Trans. No. | Date Executed. | Conv. | Grantors. | Brief. | Area. | Consideration. | Sent To. Tr. | Sent To. M. 3 | Sent To. D. 30 | Sent To. Y. 87 | Book. | Page. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 11347 | 3-20-87 | W. D. | John Smith *et al.* | 100' across N. E. of 3–50–13 and extra. | 12.00 | 1200 | | | | | K. | 113 |
| 11348 | | | | | | 60 | | | | | | |
| 11349 | | | Printed alike on both sides. | | | | | | | | | |

C. D. PURDON, M. Am. Soc. C. E., writes: I would suggest that the number given the deed be written on the right of way map, so that the deed could be quickly looked up, and that the right of way be plotted on a line on the bottom of the profile, when the profile is separate from the map.

Mr. Hall says nothing about "Cattle guard releases," which are agreements whereby the land-owner, for a consideration, releases the company from the obligation of building cattle guards on the land. These are pretty much the same as a deed, and should be recorded in the same way.

JULIEN A. HALL, M. Am. Soc. C. E.—I am much pleased to see that Mr. Harris has endorsed my paper, and I am sure he fully appreciates the many difficulties and troubles to which a man in charge of right of way is subjected. I can fully understand why his old note book, containing probably the only reliable information extant, was considered so valuable by his engineer friend in St. Paul, and it is to be regretted that many engineers do not consider it necessary to be thus exact. I suppose the reasons for this are, that some have not been properly trained and others rely very much on their memories. This latter, for present purposes, is very well; but when a man receives a company's money for his services it should be his earnest and constant endeavor to render a proper return for such compensation, and good notes cannot be too highly valued, and, as Mr. Harris' friend says, often save the company much money.

It would be well, I think, as suggested by Mr. Bates, for a clause to be inserted in the form of deed I proposed, to the effect that the land occupied by the railroad be not allowed to revert to the original owner in case of abandonment of the line, and in such case this clause would certainly save the company much money. And I think this clause should be inserted in deeds used in all States regardless of the laws of the States in which the deeds are used, as no one can tell how a lawyer may show this matter to a jury, and where there is a possibility of dealing with gentlemen of the legal profession, it is well to put a safeguard around every outpost.

I note Mr. Brush criticises my statement that a satisfactory and permanent record can be made with blue print maps. I am loth to disagree with this gentleman, and will merely say that I have had experience with blue prints only during the last ten years, and during that time I have never known one to fade. Of course, tracings made with India ink are known to be a permanent record, but my experience shows blue prints to be fully as lasting. I note also that Mr. Brush thinks that obtaining the "roving commission" given in my "Right of Way Agreement," of "a sufficient deed to so much of his lands as may be included between lines ——— from, etc.," would be impracticable. In this connection I would merely say that Mr. Brush's objection will,

without doubt, apply in some sections, but it is nevertheless a very good thing, and where it cannot be obtained the next best arrangement must be made. But this roving commission can be obtained in many sections and has been found very useful. Mr. Brush is, no doubt, also correct when he says, "Any one attempting to proceed on the lines laid down in this paper, in this portion of the country (meaning New York State, I suppose), will almost certainly fail." To this I will say, that during the last five years I have had considerable to do with getting the right of way on nearly 250 miles of railroad line in the South. We have proceeded as indicated in this paper, and have had little or no trouble in closing most of the cases satisfactorily, except where we were handicapped by the law's delays.

I think if Mr. North will read my paper more carefully he will see that I did not make it conditional that the right of way agent recommended by me should be honest only for the company, and I cannot understand why he should take this view of my remarks. I, too, think that no false promises should be made to the land owners, and that they should in all cases be fairly and honestly dealt with. But a railroad company, as is well known, is always looked upon as fair game, and the land owners will, as I said in my paper, on account of some imaginary grievance, sometimes go in "cahoot" with a lawyer and succeed in getting from five to ten times the value of the property taken, said land having been made valuable by the building of the railroad over it. A railroad generally has its hands pretty full to keep from being made bankrupt by people who abuse its property and take every advantage of it. It appears to be a fact that there are a few men managing railroads and all the world is trying to get the better of them, and a good many, by hook or crook, succeed in so doing. It is not my policy to be honest for the railroad company alone, but I look first for its interests, in each and every point, in every case that comes up; and it is the duty of others to do the same for themselves.

I agree with Mr. Charles E. Emery, that the employment of local attorneys to assist in procuring right of way will, to some extent, make the road popular, provided a suitable man can be found. I have seen this done very often, and in but one instance have I seen it work successfully. It seems to me that these local men frequently have side issues to consider and their positions are often used for their own benefit, largely more than for the interest of the company they profess to represent.

Replying to Mr. Shinn's remarks in regard to filing right of way maps: Had I thought it necessary, I would have expressed myself more fully in regard to this point. My understanding of filing right of way maps is the binding of them in heavy paste-board backs, a little larger than the maps, the maps of each county being bound in a separate atlas. These maps are properly lettered and numbered, indexed in the Map

Record book and filed in one of the map cases, just as are all of the other maps and so forth, of the company. By reference to the index any map or plan can be found at once. The right of way maps for record in counties are bound in the same kind of atlases as are those of the chief engineer's file, except that for the counties the maps consist of blue-prints of the tracings, which prints are taken on linaura, or blue-print cloth.

I note what Mr. Wallace has to say in regard to promises made to land owners by the right of way agent, to which the Chief Engineer finds it difficult to adhere. Just here there occurs to me a settlement of right of way, made by a right of way agent whom I know, and I will give the particulars in regard to it, as they will illustrate a point which I have mentioned. This agent, without any authority whatever, agreed for a side track to be built by the company to a saw-mill which had not been definitely located, as a consideration for a very small parcel of land for right of way. The agreement signed did not specify the width taken for the right of way for the main line and gave no land whatever for the side track, therefore the material for the side track became the property of the land owner as soon as put down. As the mill had not been located it could be placed any distance from the line and a local jury might compel the company to build to it. When a width of 50 feet on each side was prescribed as being a necessary width of right of way for the main line, the land owner looked on the assertion with suspicion and said to the ends of the cross-ties only would be necessary. This is also a roving commission, but with a difference from that mentioned by Mr. Brush, which is, that the company is to do all the paying and the man to whom the side track was promised is to have all the benefits. Again, a consideration of an annual pass is not uncommonly promised for right of way, and the facts of a limit of time for the pass to run, and over what lines it is to be good, do not occur to the unauthorized person making the promise. In such case it is a noticeable fact that the company may object as much as it pleases, but some local jury or legal technicality will make the agreement hold good, and the company will have to make it so. I have known of promises of money to build depots, to give a parcel of land and so forth, to be made to the company if the line is built on a certain route. The railroad company will comply with its part of the agreement, but it rarely gets the consideration promised, and is often afraid to press it's just claim, for fear of becoming unpopular. My experience is that the land owner does not need much pity. He can generally take care of himself very well and does so very successfully.

I think it proper that I should explain myself more clearly as to my expressed opinion of lawyers in right of way matters. I am not averse to them when they are honest men and good lawyers and attend promptly to what is laid before them, and when such lawyers can be found they are very valuable to the engineer, and are always appreciated by him.

But there are bad as well as good lawyers, as there are bad as well as good men in other professions and lines of work, and the railroad companies, although they give up large amounts for legal advice, do not always get those lawyers who properly attend to the company's business. It is men such as these to whom I intended to refer, and not to those who do their duty in good faith.

My paper, good or bad, has caused some discussion, and I hope that the agitation of the subject will not end here, but that several of the members will write their ideas and experiences in right of way matters, so that others who want to learn may profit thereby.

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502.
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# DISCUSSION OF PAPER No. 478, THE RAVINE DU SUD.

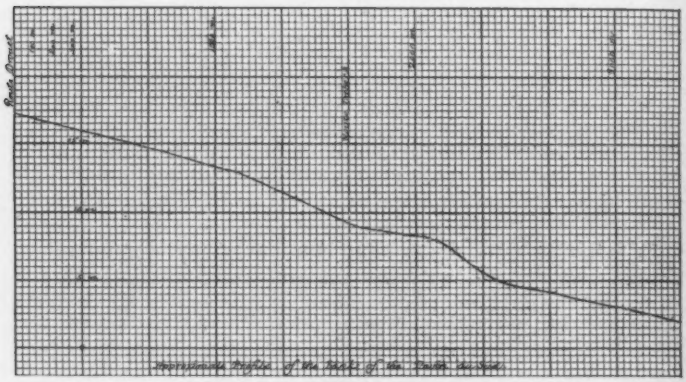
By W. R. HUTTON, M. Am. Soc. C. E.; J. FOSTER CROWELL, M. Am. Soc. C. E.; RUDOLPH HERING, M. Am. Soc. C. E.

WILLIAM R. HUTTON, M. Am. Soc. C. E.—From an inspection of the curves of level on the map it appears that the former bed of the ravine lay on top of the "cone of dejection," continually extending it and consequently reducing its own slope until it overflowed laterally and followed the steepest inclination to the plain. The accompanying profile of the present banks, made from the figured contours, shows a decided reduction of slope below route Torbeck, followed by the steep descent to the plain. Where the steeper slope above meets the flattening at route Torbeck, the stream overflows. The water remaining in the bed cuts for itself a narrow but sufficient channel as it descends the steeper grade. The enlargement of the waterway and the protection of the banks along the more level portion—perhaps even an increase of slope by a moderate excavation of the bed—would prevent overflows at this place. At the foot of the "cone" is still another and greater change of grade. The profile of the new channel shows nearly the same features.

The value of a contraction with reservoir space above in regulating flood discharges, is well known. Although the data in this case are very meager, there is reason to believe that the absence of overflow in the narrower channel below Drouet is due to the steeper slope rather than to any reservoir space in the bed of the torrent. The discharge of

8 000 cubic feet per second (4 000 cubic feet according to Mr. Hering) would fill the bed of this section in a few minutes.

The combination of creosoted timber with the concrete revetment of the banks of the Ravine du Sud would seem to be unnecessary. The concrete alone is sufficient in quantity, and its "indestructibility" is compromised by the timber, which will not last for ever.



Referring to the "bottling" theory—in other words the value of a reservoir as equalizing the discharge of a stream, the following detail may be of interest. The receiving reservoir of the Washington Aqueduct is formed by an earthen embankment about 70 feet high across the valley of Little Falls Branch, a stream of small drainage basin and discharge. The reservoir has a water surface of about 60 acres; the overflow being through a cut in the (soft) rock of a spur near the embankment. As originally designed it was 50 feet wide, the bank rising to 7 feet above the bottom of the cut. In August, 1856, when the construction of the dam was just begun, a severe rainstorm, from 5 to 6½ inches during the twenty-four hours, swelled the stream to the dimensions of a river, and carried away the work already executed.

A computation by the Prony formula—the best in use at that time—from observed flood marks, indicated a discharge of over 5 000 cubic feet per second. Supposing this quantity to flow into the reservoir beginning at its normal level, and to continue at this rate while the outflow over the 50 feet of outlet took place at a rate varying with the constantly increasing head, it was found that in about three hours the surface would have risen 10 feet, when the discharge would about equal the inflow. In consequence the bank was raised to 15 feet above normal water, and the cut widened to 100 feet. Either one of these changes

would have been strictly sufficient, but as a prudent constructor Captain Meigs, the Chief Engineer, adopted both of them.

It is doubtful if Mr. Hering has acted wisely in tabulating the results of the different formulas as given in the discussion of this paper. He certainly shows them a courtesy to which they are not now-a-days entitled. They are of no use to the expert; and they mislead the inexperienced by the inference that they are of some value, although their discrepant results should discourage him. Most of them are mere co-efficients assumed by their "authors" or derived by averaging discordant observations, and are now known to have no conceivable merit, for they take no note of conditions necessary to the solution of the problem. No one knows this better than Mr. Hering, who has done so much to promote the use of exact methods in this particular. These remarks apply to those with constant values of the co-efficient of velocity. Of the others, the formula of Humphreys and Abbot was derived by careful and skillful analysis of numerous observations upon the Mississippi River, compared with reported experiments upon other streams. The value of the comparisons was diminished by the necessity, real or supposed, of applying certain corrections to the observations made by others. However accurate when applied to the river for which it was constructed, experience has shown that this formula is not of general application.

The formula of Darcy and Bazin was a long advance upon those which had preceded it, introducing conditions which had not previously been recognized. It is now replaced by that of Kutter, of which it formed the foundation. The Kutter formula is purely experimental, constructed with the view to represent the results of all accessible and reliable observations, and at this day is conceded to be the only one that is other than by accident correct. These questions have been more fully discussed in Vol. IX, page 217 of our *Transactions*.

On page 480 of the present discussion is a table of twelve rivers on the northern slope of the Alps. The values of the co-efficient of roughness $n$ vary from 0.0294* to 0.0485; the co-efficients of velocity $c$ from 31.9 to 69.7, yet these are summed together and an average value stated for each—for what purpose it is difficult to imagine. If for comparison with the Ravine du Sud, it would have been more in conformity with the principles that have led to the construction and use of the Kutter formula to select one, or a few examples, corresponding as to conditions with the Ravine du Sud, and accept the value of $n$ given by them. The reason for assuming the value of $n$ rather than of $c$ is not sound; $c$ is to be computed from definite data, the slope, the mean depth and the value of $n$. Only the last is a matter of observation and judgment, and that within narrow limits. It is to be obtained by com-

* This is a correction of a printed error on page 480.

paring the local conditions as to roughness of bed with that of other streams for which the co-efficient $n$ has been obtained by experiment.

Mr. Crowell did not expect much from the formula used, Stevenson's, which, however, answered his purpose of comparing discharge in the typical section with the discharge in the new, despite the remarkable errors pointed out by Mr. Hering. As he has attributed to the new channel a third more carrying capacity than to the typical section, accuracy, either relative or absolute, was not necessary.

J. Foster Crowell, M. Am. Soc. C. E.—In reply to Mr. Hutton, the author of the paper would say: A short distance below the route Torbeck, opposite station 1800 (meters), and indicated on the map accompanying the original paper (see Plate LV), are two small houses, one of which is a one-story frame structure covered on the outside with lath and plaster. This little building stood through the great flood which carried away the protective works at station 800. The outside plaster was washed off by the water at that time, according to eye-witnesses, to a height of about 3 feet above the ground, and the remaining plaster thus gives a well-marked water-line, which was probably the maximum of the flood. This fact would indicate that the overflow below Torbeck, referred to by Mr. Hutton, was due to the insufficiency of the water-way further down stream and not to the flatter slope here. If there had been any considerable velocity in the flow, the frail building would have been carried away. The water doubtless spread slowly out, forming a lake, while the flood was rushing out through the gap it had made in the revetment, 1 kilometer further up stream. The contours show that the old bed near where the break occurred is not on the highest part of the "cone of dejection," which would, on the contrary, appear to be on the other side (the western side) of the present bed.

But whatever the immediate cause, the original plan comprehends all of the three features which Mr. Hutton suggests, viz.: "the enlargement of the water-way, the protection of vulnerable portions of the banks and an increase of slope by a moderate excavation of the bed," the latter being possible by adopting for the bottom of the new channel a uniform gradient of $26\frac{5}{10}$ feet per mile, from about station 700 to station 2200 (p. 477), as against 17 feet to the mile, which is now the slope through the portion of the stream below Drouet not overflowed, and where the typical section was measured. As to the cause of the absence of overflow at the latter point, Mr. Hutton is undoubtedly correct in his view that it is the steeper slope relative to the compartment just above, which has been described as the "reservoir compartment." This does not, however, conflict with the view expressed in the paper as to the effect of the reservoir space above the route Drouet (pages 473 and 476), in reducing the original velocity of the torrent and storing up the accumulating flood water so as to give time for the "neck of the bottle" to empty it.

The use of creosoted timber in connection with the concrete revetment, which Mr. Hutton criticises as unnecessary, is proposed as a means of obtaining immediate security for the concrete walls against concentrated scour, in the event of a flood during the progress of construction, and lateral stability until such time as the embankment backing can be fully completed and made efficient. The formation at the most vulnerable points consists of a thin covering of clay overlying a bed of sand, requiring a very deep foundation if concrete alone were to be used. Ultimate reliance for the stability of the wall can be obtained from the heavy embankment of small stone and clay, which, as it will be formed of surplus material from the channel excavations, will add little to the cost. The timber below the plane of saturation is designed for a permanent foundation. The extension of the timber members above that plane is for the purpose of temporarily giving the required stability in case of a flood intervening during construction, and it is so disposed as to permit of its gradual decay without impairing the integrity of the concrete wall or the necessity of renewal. By the use of the timber a very considerable saving in the quantity of concrete can be effected; it also permits of the forming of the embankment backing, either in advance of, during, or after the readiness of the concrete to retain it, a very important consideration in a work so remote from the source of supplies.

A word as to Mr. Hering's action in tabulating the results of the different formulas may not be inappropriate here, for it was at the writer's express solicitation, and perhaps only on that account, that he contributed it to the discussion. It appears that he has brought out one of the most important points in the discussion, by making clear to those of us whose special training does not fit us to readily discriminate as to the relative worths of different recognized flowage formulas, the essential points of difference between the true and the false; a result to which Mr. Hutton has also contributed by his comments on the tabulation.

RUDOLPH HERING, M. Am. Soc. C. E.—Mr. Hutton has called attention to the fact of my having averaged the results of certain river gaugings, and very properly takes exception to applying this method in a general way. It is curious that I should have exposed myself to this criticism when I have always strongly opposed such averages, when it was one of the criticisms I made myself upon Kutter's original table, and when I took such pains to compile and have printed in the translation of Kutter's work (made by Mr. Trautwine and myself) all the many individual gaugings, instead of Mr. Kutter's averages for them. I quite agree with Mr. Hutton on this question. My object in giving, besides the individual values in Table No. 2, also the average "in round numbers," was simply to have a single quantity with which to show the effect of the different formulas still occasionally quoted, and particularly Mr. Crowell's modification of Stevenson's formula. The latter was the sole

object of my discussion rather than to suggest the best co-efficient for the Ravine du Sud. The average assumed by me—sufficiently near for the above purpose—was confined to those streams whose beds, according to the descriptions, were approximately like that of the "Ravine," and it also agreed almost exactly with the values obtained from the two streams, "Isar" and "Saare," which most nearly resembled it in slope and in mean radius.

In reply to Mr. Crowell, who thinks my comparison is not fair to the Stevenson formula, because I do not represent it "in the original form," it is right to point out that, while in Table No. 1 the eighth formula is Mr. Crowell's modification, the sixth is the original Stevenson formula "for large streams," as contained in Humphreys' and Abbots' report on the Mississippi River, page 220. It is true that Mr. Stevenson also proposes a co-efficient $c = 69$ (when the formula is reduced to feet and seconds), but this is intended only "for small streams under 2 000 cubic feet per minute," or such as have less than 1 per cent. of the probable discharging capacity of the Ravine du Sud! It is this smaller co-efficient reduced to other units of measure which Mr. Crowell applies to the Ravine du Sud, and finds the results to correspond closely to those of the Kutter formula. Surely he does not mean that such is more fair to the Stevenson formula.

In conclusion, I wish to remove a possible impression to the effect that I was criticising Mr. Crowell's ultimate designs unfavorably. Such was not my purpose. The manner in which he has applied Stevenson's formula (see pages 476 and 477) eliminates errors in his case. He assumes a hypothetical flood, finds from the measurable elements a hypothetical discharge, and uses the latter simply to ascertain for the same channel a new cross section for a different slope. In this operation the hypothetical discharge cancels, as does also the co-efficient $c$, when constant. Therefore, it is entirely immaterial what the values are, either of the discharge or of the co-efficient $c$.

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503.
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# THE AMERICAN RAILROAD VIADUCT.—ITS ORIGIN AND EVOLUTION.

By J. E. GREINER, M. Am. Soc. C. E.

WITH DISCUSSION.

A new era in the design of a certain type of bridge began in 1868, with the construction of the Bullock Pen Viaduct on the Cincinnati and Louisville Short Line Railroad, "now L. and N.," and the history of the American Railroad Viaduct is mainly a statement of its development since that time.

From the beginning of railroads, engineers have been continually directing their efforts to produce structures which would not only fulfill all requirements, but which at the same time might be superior and bolder than any before; consequently each new form of truss, column or detail gave to the profession valuable suggestions of what could yet be done in so fertile a field for inventive ingenuity. These suggestions naturally formed the nucleus from which new ideas were evolved, until by the continued addition of improvements and the elimination of palpable fallacies of design, the present standard type of single quadrangular and the later, more economical, but not quite so simple, Pegram trusses, were gradually produced.

A well known engineer has said that "it requires a great deal of nerve for any one to say that he originated a certain type of bridge structure or a specification, when it all came about by some one adding a little to what some one had already done," and the viaduct is no excep-

tion, since it was not of spontaneous production, neither was its conception quietly nurtured in the brain of some engineer, from whence it sprang upon public notice fully matured. It followed a very gradual course of development, indications or suggestions of certain features being distinctly traced to the earliest timber trestles. The general plan of these trestles was practically the same as is now used, being formed of bents stationed at short intervals, connected together at their tops and at intermediate joints by longitudinal lines of stringers or struts. Each bent consisted of two or four legs with cap and sill, all cross-braced, the outer legs having a batter. An outline sketch of such trestles is shown on Plate LXXVIII, Fig. 1. Of course as the depths of ravines or depressions to be crossed increased, the general character of trestles was modified somewhat, the most striking example being the old Portage Viaduct, a structure 800 feet long and 234 feet high from bed of river, designed by Silas Seymour in 1851, built in 1852, and completely destroyed by fire in 1875. This viaduct was always considered the boldest attempt ever made in timber trestles.

The first notable change made in the established wooden trestle, was in the Carey street trestle over the Baltimore and Ohio Railroad tracks in Baltimore, built by Wendal Bollman, in 1851. Here for the first time the successive bents were held together longitudinally by iron diagonal rods connecting the top of one leg to the bottom of another. These rods took hold of pins passing through cast shoes at the bottom of the posts, and at the top were provided with screw ends and nuts which bore against cast washers on the upper surface of the chord pieces or stringers. The bents were in two stories and consisted of two legs, cap, sill and intermediate strut, cross-braced, all parts being of wood except the longitudinal tie-rods and cast shoes. A section of this structure is shown in Plate LXXVIII, Fig. 2. The old Antietam trestle on the Washington County Branch of the Baltimore and Ohio Railroad was of similar construction. It was, however, two stories high throughout.

Since "the first impulse to the general adoption of iron for railroad bridges was given by Mr. Benjamin H. Latrobe," it is not surprising that the first iron trestles were designed by his assistant, Mr. Albert Fink, Past President Am. Soc. C. E., built by the Baltimore and Ohio Railroad Company in 1852, and erected early in the year 1853. These were known as the Buckeye and Tray Run viaducts. They crossed ravines on Cheat River, the former being 350 feet long, 46 feet high from top of wall, and

28 feet wide between hand-railing, and the latter 445 feet long, 58 feet high and 28 feet wide. All parts of the trestles were of cast-iron except the tie-rods, the general design being shown on Plate LXXVIII, Fig. 3. These structures rested on continuous walls of masonry, and having been built in sections of about 125 feet in length, could expand and contract with changes of temperature. It may be interesting to learn that it was the original intention to build the walls to full height, but after having reached a certain elevation, the engineer considered it not advisable to continue, owing to evidences of weakness, and as a result of this decision, Mr. Fink designed the structures here described. The Buckeye was removed in the year 1884, and the walls, after being properly strengthened, were built up as originally intended. The Tray Run was replaced by a modern structure in 1887.

In 1852, a tower lighthouse at Cary's Fort Reef was designed. This was composed of four columns, one at each angle, connected together in all directions by struts and rods in the same general manner as are the towers of viaducts built at the present time. The tower was of two or more stories, and the posts or legs had a batter both longitudinally and transversely, instead of being battered in a transverse direction only, as is now adopted for viaducts. The lighthouses at Sand Key designed in 1853, Sombrero Key (Dry Dock 1857), Shell Keys and Alchapalaya in 1859, were of similar construction.

The Crumlin Viaduct, begun in 1853 and completed in 1857, on the Taff Vale Extension Railway, South Wales, Messrs. Liddell and Gordon as engineers, is in all probability the first iron viaduct resting on independent iron towers. The main part of the viaduct consists of seven spans of wrought iron Warren girders 150 feet center to center, and six towers arranged in tiers, each containing fourteen cast-iron columns. The greatest height above the surface of the water is about 200 feet. A section of this viaduct is shown on Plate LXXVIII, Fig. 4.

On Plate LXXVIII, Fig. 5, is an outline sketch of the iron structure over Jordan Creek, on the Catasauqua and Fogelsville Railroad, designed and built by the late Mr. F. C. Lowthorp, F. Am. Soc. C. E., in 1856 and 1857. The total length was 1 122 feet, consisting of nine spans of 100 feet each, and two spans of 111 feet each, supported on cast-iron trestle towers about 89 feet high. All compression members were of cast-iron, and tension members of wrought-iron rods, capable of adjustment. In 1889 the Catasauqua and Fogelsville Railroad were hauling cars

weighing, when loaded, 88 500 pounds, and not feeling safe with such heavy loads on the old bridge, they had it replaced by a more modern structure, resting, however, on the original masonry erected by Mr. Lowthorp, the only change being three new coping stones.

From 1857 to 1868 there were no material improvements made in the general design of viaducts, superior to those embodied in the Crumlin and Jordan River structures; and in these cases, it will be noticed, the towers were grouped together on top of solid masonry piers. These piers being massive, required great care in preparing safe foundations in unfavorable situations; besides, the necessary large outlay for such structures induced many railroads to adopt cheap wooden trestling in preference. Engineers, therefore, began to study more closely the principles of true engineering in relation to iron viaducts, and directed their attention toward designing a system of iron piers which should be of cheap construction, adapted to all conditions, and free from inherent defects.

The first evidence of the result of such investigations is seen in the Bullock Pen Viaduct, designed by Smith, Latrobe & Co. in 1867, built in the same year, and erected on the Cincinnati and Louisville Short Line, now "L. and N.," in 1868. The structure was 470 feet long, the maximum height 60 feet, and of the same general design as the viaduct Plate LXXIX, Fig. 1. Mr. Frederick H. Smith, M. Am. Soc. C. E., a member of the firm of Smith, Latrobe & Co., personally made the plan, although there were suggestions from, and consultations with, both C. Shaler Smith, M. Am. Soc. C. E., and C. H. Latrobe, M. Am. Soc. C. E. Mr. F. H. Smith, however, considered that he originated certain features entirely independent of any other assistance, claiming as new and original with himself the following, which form part of his specifications in Letters Patent, No. 89 948, filed at Washington on October 13, 1868, and issued May 11, 1869:

"*First.*—Anchoring the tops of iron or steel piers of bridges by means of longitudinal diagonal stays, or equivalent tension members, to the feet or pedestals of other piers or abutments, so that the pier can be formed of but two columns, and still have the great longitudinal base afforded by the spread of the longitudinal diagonal stays to give it stability under the action of temperature or moving load.

"*Second.*—In combination with the foregoing system of stays, iron or steel columns, stiffened by means of up-and-down struts or tension-rods and cross-struts or tension-rods at such point in the height of the columns as will prevent flexure.

"*Third.*—Stiffening iron or steel bridge piers by means of longitudinal rods or struts, anchored to or abutting against masonry, and connecting therewith the piers, and the piers with other piers, at such points in their heights as will prevent flexure.

"*Fourth.*—The combination of iron or steel piers of bridges with the longitudinal diagonal stays, and up-and-down stiffening system and the longitudinal stiffening system."

The firm was building five other viaducts about the same time for the same road, all of the general style of the Bullock Pen.

The Running Water Viaduct, on the Nashville and Chattanooga Railroad, erected in 1869, and the Lyon Brook Viaduct on the New York and Oswego Midland Railroad, Plate LXXIX, Fig. 2, built by the same company about the same time, were similar in design, the former consisting of one Fink span of 95 and 692 feet of trestling, the maximum height being 115 feet, and the latter of one span 100 feet long and 720 feet of trestling, the maximum height being 155 feet. In these two structures the longitudinal diagonal bracing and timber strutting do not extend from abutment to abutment, as was the case in C. and L. S. L. trestles, but the ends of the long channel spans rest upon trestle-bents which are connected to adjacent bents by wrought-iron struts and tie-rods, thereby forming complete iron towers of two bents each, with a 30-foot tower span between the bents. In these structures there appears for the first time the common tower, composed of two bents of two legs each, braced together in all directions, the legs having a transverse batter only, and the bents being connected at their tops by a free or swinging span. This is the typical braced tower as used in American viaducts, and its use in these cases was not due to originality of conception so much as to the necessity of the cases, which demanded a pier stable in itself at each end of the long open span, for the continuous lines of longitudinal strutting to bear against; since at that time it was thought essential to continue such strutting from abutment to abutment. By using these braced towers the structure was practically composed of two trestles, each of which was complete in itself, but connected by an open span so as to form one whole.

The features in the foregoing trestles, which were original with C. Shaler Smith and C. H. Latrobe, can be briefly stated as follows:

*First.*—Cast-iron foot-boxes interposed between and forming the bearings for the column sections, in combination with longitudinal

diagonal ties connecting the joints of any one tier with those of another tier. *Second.*—The construction of the cast-iron postcaps, foot-boxes and joint-boxes. *Third.*—The combination of a series of independent or isolated bridge piers, with an intermediate span or spans of truss connecting the same. *Fourth.*—Yoke and screw end attachment for longitudinal diagonal ties.

Messrs. Smith, Latrobe & Smith, up to this time (1869), believed that it was quite necessary to make the continuous longitudinal struts of wood in order to prevent the contraction and expansion which would follow the use of a similar system of iron struts; but in the design of the towers at the ends of the channel-span in the before-mentioned Running Water and Lyon Brook trestles, Mr. C. Shaler Smith conceived a means of doing away with wooden struts and substituting iron in their place, and in a general design of a viaduct made in 1870 he contemplated the use of iron throughout, and provided for expansion and contraction by omitting all bracing in certain panels or bays, thus forming a structure "made up of fixed piers composed of any number of panels of trestles alternating with spans of truss having one or both ends loose, so as to permit of contraction or expansion." Plate LXXX, Fig. 1, is a copy of this general design which accompanied his application for the patent, No. 111 010, granted January 17th, 1871.

The Verrugas Viaduct, on the Lima and Oroya Railroad in Peru, built in 1871 by the Baltimore Bridge Company, and designed by Associate Engineer C. H. Latrobe personally, was the first wrought-iron structure built by the company embodying the principle of independent braced piers, as set forth in Mr. C. S. Smith's specifications. This structure consisted of three towers or piers and four Fink trusses, the total length being 575 feet. The central pier was 252 feet high, and the others 146 and 179 feet. Each tower contained three bents, and each bent composed of four columns braced together in all directions. A full description and cause of collapse, in 1889, may be found in the *Engineering News* of July 27th, 1889, and December 27th, 1890, and also in the *Engineering and Mining Journal* of January 24th, 1891.

These structures as built by the Baltimore Bridge Company, became very popular. In less than five years after the Bullock Pen Viaduct was erected, the company had built over 15 000 lineal feet of railroad viaducts, and since letters patent were granted in England, France and Belgium, as well as in the United States, we are safe in presuming that such structures were originated in this country.

In 1869, Mr. Thomas C. Clarke, M. Am. Soc. C. E., designed a viaduct approach for the proposed bridge across Blackwell's Island, New York. (Plate LXXXI.) In a recent paper read before the American Society of Mechanical Engineers, he states that at that time, not wishing to use any perishable material like wood, the difficulty arising from changes of length due to changes in temperature was avoided, by simply leaving out the longitudinal bracing and struts of each alternate bay, thereby giving a series of braced towers 30 feet long, connected by girders of the same length resting on their tops, and having a sliding motion at one end. He afterward found it expedient to lengthen these intermediate girder spans to the greatest length that could be transported from the shops to the site, about 60 feet, and believes himself to be the originator of the well-known American Railroad Viaduct. This seems to be true, since, although Mr. C. S. Smith made application for letters patent on a similar general design in 1870, Mr. Clarke had anticipated him a whole year.

About the same time (1870) Mr. C. Bender secured letters patent on the type of viaduct shown on Plate LXXXII, Fig. 1, and modestly claimed that he could build such a bridge "cheaper and more perfect than any other one in existence." He seems to have gotten the idea of his design from an ordinary kitchen table, and refers to the spans with overhanging ends as "table spans." This system differs from those previously designed, by combining the piers or trestles with the spans themselves, thereby using the stiffness of the truss itself against flexure, as the element of stability, "likewise as the frame of the common table keeps in position the table legs." If any such structure has ever been built in this country, the author has been unable to ascertain when or where. This invention is mentioned here not because it in any way contributed to the evolution of the typical viaduct, but merely as showing the general aim of engineers at this time.

In 1871 Mr. Edward Serrell, of New York, invented some improvements in iron viaducts and claimed as his invention a "metallic tower made of columns around a central column that is permanently attached to the foundation, and the surrounding columns are provided with foot plates in shoes that are attached to the foundation so as to allow for expansion and contraction, but to hold the parts properly in position." Details of this arrangement are shown on Plate LXXXII, Fig. 2. The most interesting part of Mr. Serrell's design is his method of providing for

expansion, as can be seen from Fig. 2[a], where the arrows indicate the direction of motion, and Fig. 2[b] the method of keeping this motion in a straight line. The principle shown in the sketches is now quite commonly used at the sliding ends of plate girders and stringers; and the same could be applied with great advantage to the alignment of viaducts, if in a four-legged tower one column be permanently fixed and the others be allowed to move in the directions shown by arrows in Fig. 2[a]. The author does not know whether the application of the principle of sliding motion shown in Plate IV, Fig. 2[a], has ever been used on viaducts, and believes that the double motion obtained by the arrangement shown is new, although there are other means of providing for sliding of legs, all more or less satisfactory.

In 1875, Mr. G. Bouscaren, M. Am. Soc. C. E., built his first viaduct on the Cincinnati Southern Railroad. This is known as the Horse Shoe Run Viaduct* (Plate LXXX, Fig. 4), and was made in imitation of similar structures built by the Baltimore Bridge Company. Mr. Bouscaren consulted with Mr. C. S. Smith at the time, and the latter still considered it essential to have a continuous line of diagonal rods from the top of the first to the feet of the last trestle bent in a group, thus making the number of bents in any particular group, dependent on the height. In 1876 Mr. Bouscaren adopted braced piers composed of two trestle bents only, braced together in all directions, no matter what was the height of the structure. The foot of one post was fixed to the masonry of the pedestal, and the other three were allowed to move on friction plates with the changes of temperature. This was a very marked improvement on his previous types, inasmuch as he avoided the necessity of frequent readjustment of diagonal bracing-rods. Fishing Creek Viaduct (Plate LXXX, Fig. 5), built in 1876, is of this type. In 1878 an additional advance in the economy of design was made by proportioning the length of span between piers to the height of the structure; McKee's Branch Viaduct (Plate LXXX, Fig. 6) is an example of this type.† In 1881 the same engineer designed for the same road the first viaduct on rocker piers, made of a single trestle hinged at both ends. Mr. Bouscaren considers that this type is far superior to all others when circumstances will permit of its use. The transmission of stresses is more direct (no adjustment whatever is necessary), and they are more

* Designed and constructed by the Keystone Bridge Co. See Appendix.

† Designed by C. L. Strobel, and approved by G. Bouscaren, Chief Engineer.

uniform and better defined than in any previously designed structures. The pin-bearing shoes, at the feet of the trestle posts on one side, are fixed to the masonry pedestals, and those on the other side are free to move on friction plates.

A great number of viaducts copied from those designed by C. S. Smith and G. Bouscaren have been built, but the greatest height of towers yet attained seems to have been in the Kinzua Viaduct, where the greatest height of any tower is 297 feet, or from base of rail 301 feet. The viaduct was built by Clarke, Reeves & Co., 1882. Drawings and full description of the same may be seen in the Album of Designs issued by the Phœnix Bridge Company.

The new Portage Viaduct (Plate LXXX, Fig. 3), G. S. Morison, M. Am. Soc. C. E., engineer, built in 1875, if not the very first, seems to be the first of particular note which had towers of two bents only for the different lengths of spans. This structure replaced the old wooden viaduct, some of the original piers being used. These piers being 50 feet, center to center, the designer could have made all spans 50 feet, but considered the adopted arrangement preferable. This type of structure therefore antedates by several years similar types designed by G. Bouscaren for the Cincinnati Southern Railroad.

Since the year 1878, general designs have been practically uniform, embodying the distinctive features which make such structures the most economical; but the Kinzua, so often spoken of and illustrated as a striking example, still holds its own against all comers for best adaptation of design to existing circumstances.

The question has been often asked, "Who was the originator of the American viaduct?" It is now time that the question be settled once for all, and there is no society better able to do so than the American Society of Civil Engineers, which includes among its members many who were important factors in the early progress of bridge engineering.

In the foregoing history the facts given are perfectly authentic, but there may be other structures known to some, which could be considered as additional links in the chain of evolution. Be this as it may, there are ample examples given for any one to trace the gradual development of viaducts from the early timber trestles; for in these structures we see the bents composed of two or four legs, and the outer legs battered, built in stories and cross-braced, a very similar construction to the bents of later viaducts in iron. The second step is seen in the old Carey Street

trestle built by Bollman in 1851, where he anchored the tops of bents to the feet of adjacent bents, or, in other words, introduced a continuous system of longitudinal diagonal bracing. Then came the complete iron bents in the Tray Run and Buckeye trestles; next the towers composed of four columns, arranged in tiers, braced in all directions; and finally the Crumlin and Jordan Creek viaducts, in which the different spans rested upon built up iron towers. This is the end of the first stage of development, and includes all features up to 1867.

If, then, up to this time we find bents, cross-bracing, longitudinal bracing and towers, what was novel in the Bullock Pen trestle? Merely the combination of some of these features, and their adaptation to wrought-iron construction. As said before, this structure was the beginning of a new era, and it must be acknowledged that Mr. F. H. Smith, not C. Shaler Smith, was the actual designer and should have full credit in introducing a new combination, therefore a practically new style of structure, in wrought-iron. Mr. C. S. Smith, however, was closely connected with this work, and the trestle has a feature, namely, the connection of the longitudinal diagonal bracing with intermediate joints on the columns, which was suggested by him. F. H. Smith introduced the continuous line of timber strutting which anchored the bents to masonry abutments. In the Running Water and Lyon Brook structures, the distinctive feature is the complete iron tower composed of two bents of four legs each, braced in all directions by iron rods and iron struts, besides having a regular span to connect the bents which form a tower, originated by C. S. Smith.

Finally we come to the structure composed of towers with spans connecting the bents of the same, alternating with free or open spans. Mr. Clarke justly claims to be the designer of this, the typical viaduct, and the facts seem to uphold his claim. While it is true that Mr. C. S. Smith patented such a structure, it is a well known fact that none of the patents taken out by members of the Baltimore Bridge Company could stand the tests of a court trial in view of what had been done before, and they soon became public property. The first structure embodying the principles of such a type was the Verrugas, built by the Baltimore Bridge Company in 1871. It is true that it embodies certain ideas concerning the number of bents in a tower which finally came into disuse, but nevertheless it can surely be considered typical.

It was the original intention to embrace in this paper a discussion of

construction, details, etc., also to develop formulas for weights of viaducts, but the historical portion having consumed considerably more time than was anticipated, the author finds it necessary to close for the present, trusting that others better qualified will at some early date present the Society with a paper on viaduct construction, a subject which has heretofore received but a small part of the consideration to which it is entitled.

In conclusion, the author would like to call attention to the loose way in which the terms "trestle" and "viaduct" are applied, even by well-known and intelligent engineers. Of course we all know that the usual definition of a viaduct is "a bridge of any style which carries a road over a ravine or depression where there is little or no water." A definition of a trestle would be practically the same with a limit to the style, although we feel instinctively, as it were, that the term "trestle," applied to the Kinzua Viaduct, would be a misnomer. Where, then, does the trestle end and the viaduct begin?

Further, suppose we have two profiles which would admit the use of the same structure. In one case there would be no water, but in the other, water would cover most of the depression. Should we call one of these structures a viaduct and the other simply a bridge, or should they both be viaducts? The derivation of the word will not help us, and it seems preferable that the name should designate the style rather than the location. In this sense a trestle would be a bridge of wood or metal in which the different spans are supported directly upon trestle-bents not connected in groups or towers; and a viaduct, a bridge of wood or metal in which the different spans are supported directly upon legs of towers composed of two or more bents braced together in all directions. The above definitions, while not meeting English practice, will undoubtedly distinguish American structures, and if adopted, would do away with all looseness in this connection.

# DISCUSSION.

GEORGE S. MORISON, M. Am. Soc. C. E.—Reference has been made in this paper to the new Portage Viaduct. I ought to state that although this was designed by myself and built under my direction, the particular arrangement of towers used was fixed, first, by the piers of the old wooden viaduct, and, secondly, as suggested by others. If, as the writer says, this was the first structure of its class, the credit for any originality in this way does not belong to any one person. I have thought that it might be interesting to compare this Portage Viaduct with another viaduct built by myself almost exactly ten years later, namely, the Marent Gulch Viaduct on the Northern Pacific Railroad, the height of the iron work of which differs less than a foot from the height of the iron work of the Portage Viaduct, and the length of which is very nearly the same. The Marent Gulch Viaduct is, however, a symmetrical structure, which the Portage Viaduct is not. As I shall soon present a paper describing this interesting work in detail, I will reserve further remarks until then. I would say now, however, that this structure is built entirely of iron.

G. BOUSCAREN, M. Am. Soc. C. E.—For the purpose of comparing the relative value of this plan and other plans, it would be very interesting to know the weight of iron in the total viaduct and the area in square feet of crossing between the grade line and ground line. The comparison of these data is the best way of arriving at the relative economy of the different plans. At the time when I made the modifications of the plans on the Cincinnati Southern, it was such a comparison that led me to adopt longer spans. Where the masonry foundation had been put in for 30-foot spans, I found it cheaper to leave the short spans out and substitute 60-foot spans instead. The result I arrived at was, that the most economical length of span was about one-half the height of support. The relative lengths of span and piers here conform with that rule for the center, but the spans would be a little too long for the ends.

ROBERT MOORE, M. Am. Soc. C. E.—It strikes me the effort made by the author to confine the use of the word viaduct is open to criticism. Under the limitation proposed I do not know what we should do with the old fashioned stone viaduct, which would then be without a name. I doubt much whether it is practicable to limit the word in that way. I think the etymological use of the word is the best. According to this a viaduct is a structure which carries a road, whilst an aqueduct is one which carries a canal. The suggestion that the credit of the invention of the modern railroad viaduct should be given where it belongs is a very good one, yet I presume it will be found impossible to ascribe its origin to any one person. Probably every viaduct embraces ideas due to many persons, so that I question whether it is practicable to

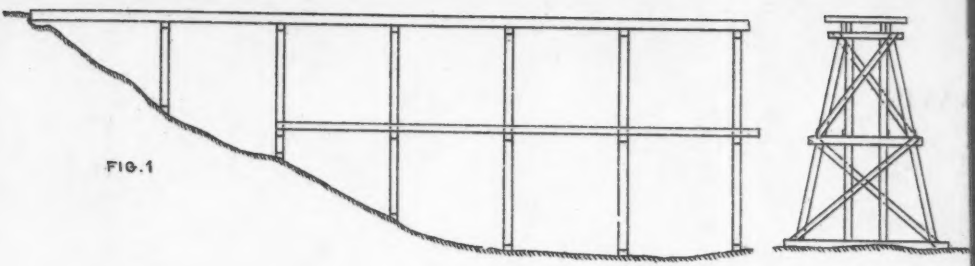


FIG. 1

COMMON TIMBER TRESTLE

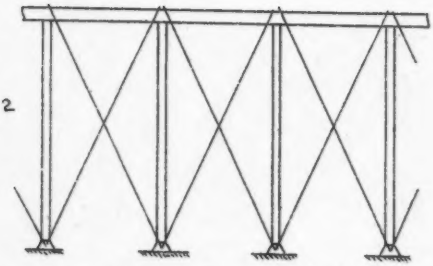
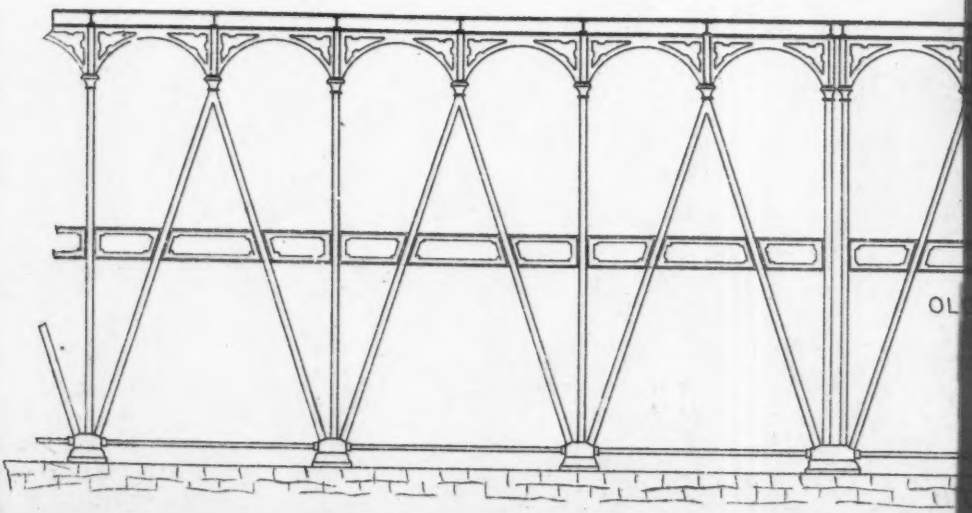
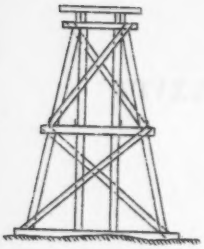


FIG. 2

OLD CAREY ST. TRESTLE-BALTº Mº
1851





IMBER TRESTLE

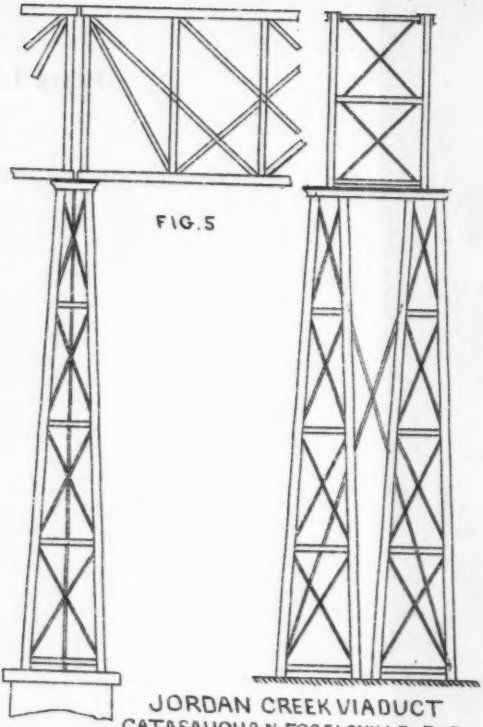


FIG. 5

JORDAN CREEK VIADUCT
CATASAUQUA & FOGELSVILLE R.R.
1856-7

FIG. 3

OLD BUCKEYE VIADUCT
B & O.R.R.
1852-3

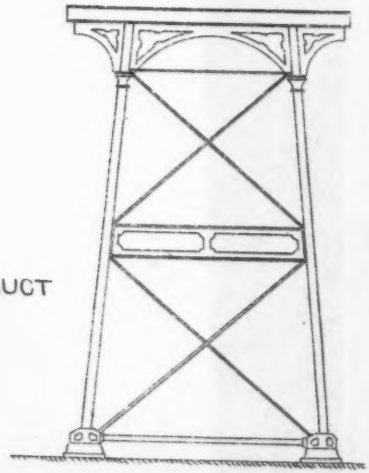


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PLATE LXXVIII
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GREINER ON
THE ORIGIN OF THE R.R. VIADUCT.

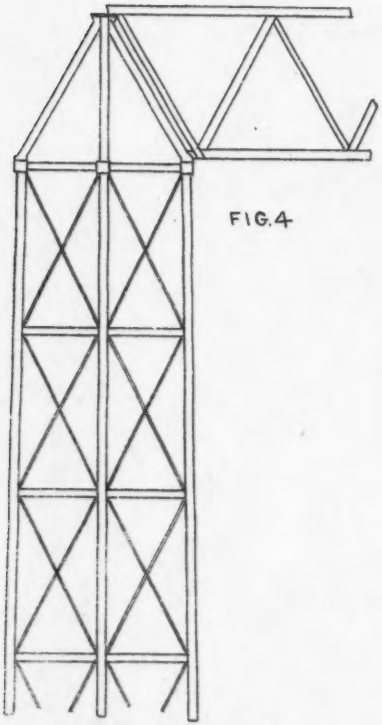
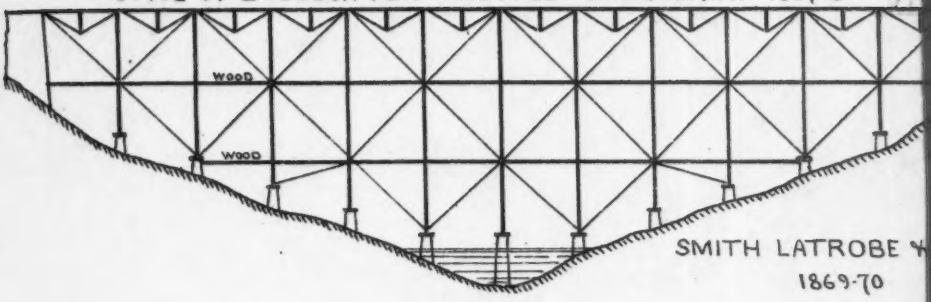


FIG. 4

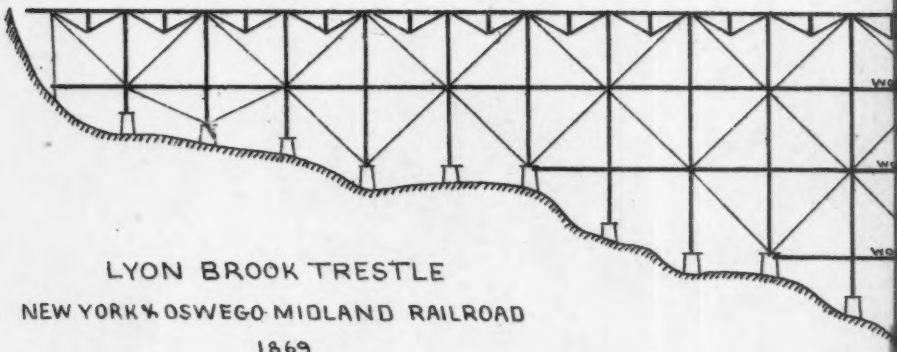
CRUMLIN VIADUCT
SOUTH WALES
1853-7

# ORIGIN AND EVOLUTION OF THE AMERICAN RAILROAD VIADUCT.

STYLE OF BULLOCK PEN TRESTLE- C.&L.S.L.R.R.- 1867-8




SMITH LATROBE &
1869-70



LYON BROOK TRESTLE
NEW YORK & OSWEGO MIDLAND RAILROAD
1869

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R.R.- 1867-8

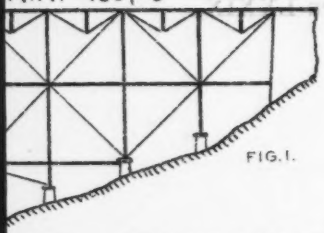

FIG. 1.

SMITH LATROBE & SMITH
1869-70

# ORIGIN AND EVOLU

## OF THE

# AMERICAN RAILROAD V

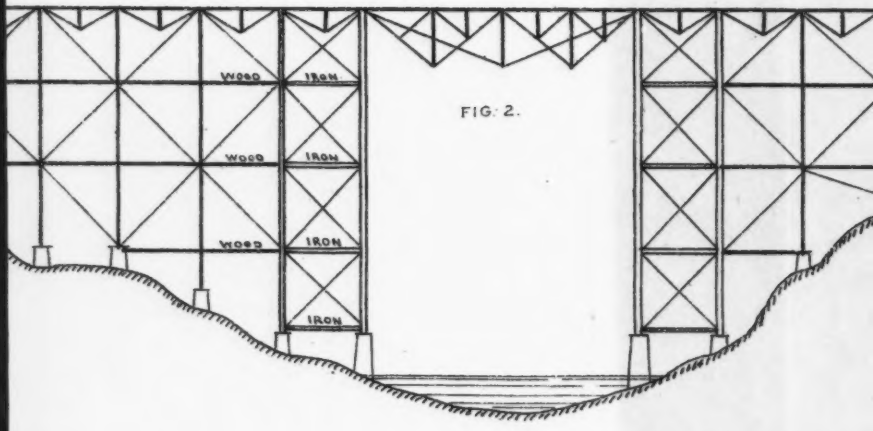


FIG. 2.

PLATE LXXIX.
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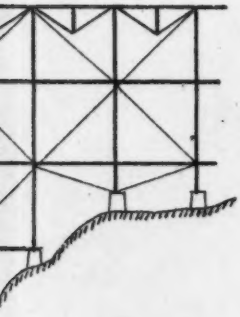
GREINER. ON
ORIGIN OF THE R.R. VIADUCT.

# VOLUTION

## IE

## OAD VIADUCT.



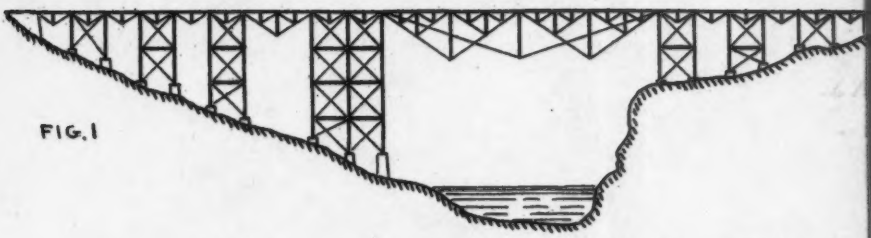


FIG. 1

GENERAL DESIGN 1870 - C. SHALER SMITH.
OLD VERRUGAS VIADUCT - OF THIS TYPE - 1871

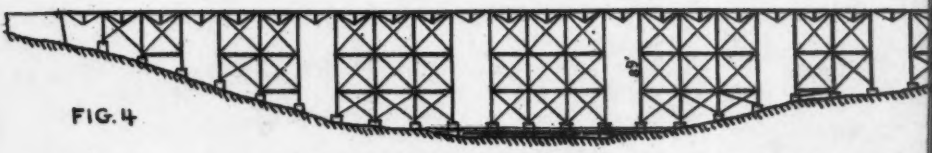



FIG. 4

HORSE SHOE RUN C.S.R.R. 1875 - G. BOUSCAREN

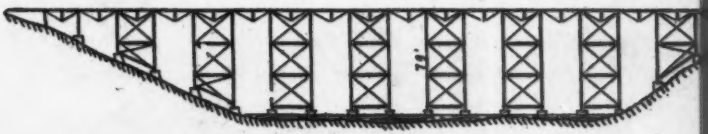



FIG. 5

FISHING CREEK C.S.R.R. 1876 - G. BOUSCAREN
DESIGN OF APPR. VIA. OF BLACKWELL'S ISLAND BR. OF THIS TYPE -

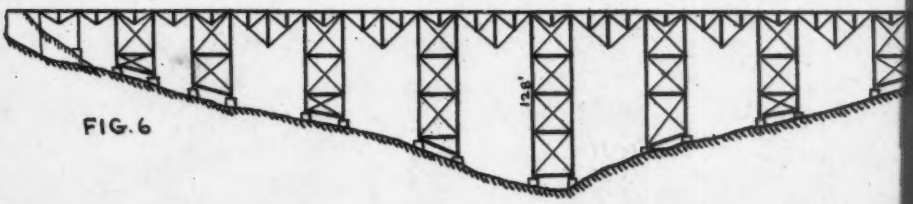



FIG. 6

McKEES BRANCH C.S.R.R. 1878 - G. BOUSCAREN.

HALER SMITH.
ISTYPE-1871

75 - G. BOUSCAREN

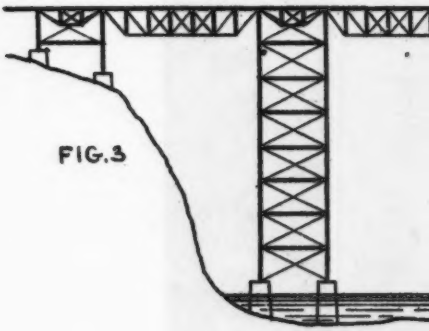


FIG. 3

NEW PORTA
GEO. S. MORI

- G. BOUSCAREN
D BR. OF THIS TYPE - 1870 - THOS. C. CLARKE

- G. BOUSCAREN.

ORIGIN A

O

AMERICAN RA

PLATE LXXX.
TRANS. AM. SOC. CIV. ENG'RS.
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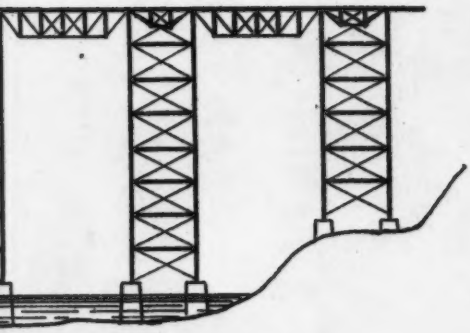
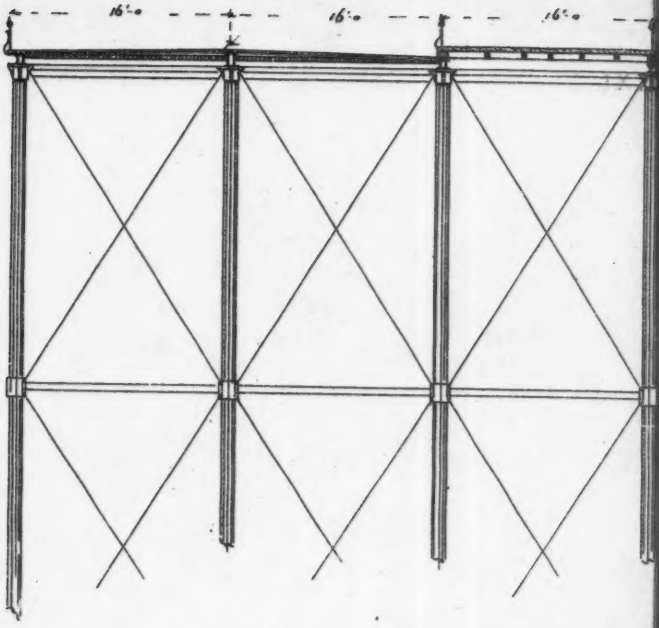
GREINER. ON
THE ORIGIN OF THE R.R. VIADUCT.

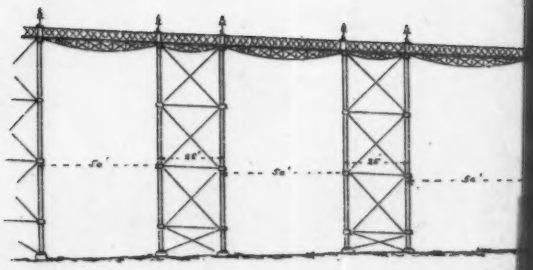


PORTAGE VIADUCT
S. MORISON - 1875

# GIN AND EVOLUTION
# OF THE
# CAN RAILROAD VIADUCT.

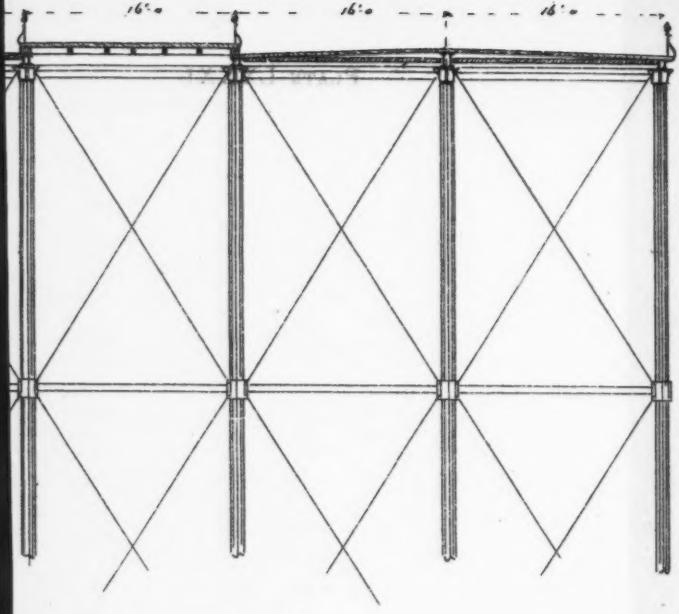



CROSS SECTION.

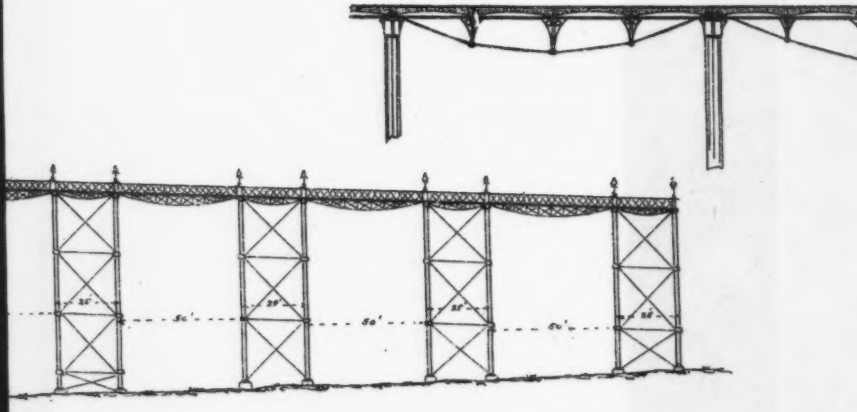



ELEVATION.

designed by Thomas C. Clarke
Brooklyn. N.Y.
1869.




CROSS SECTION.



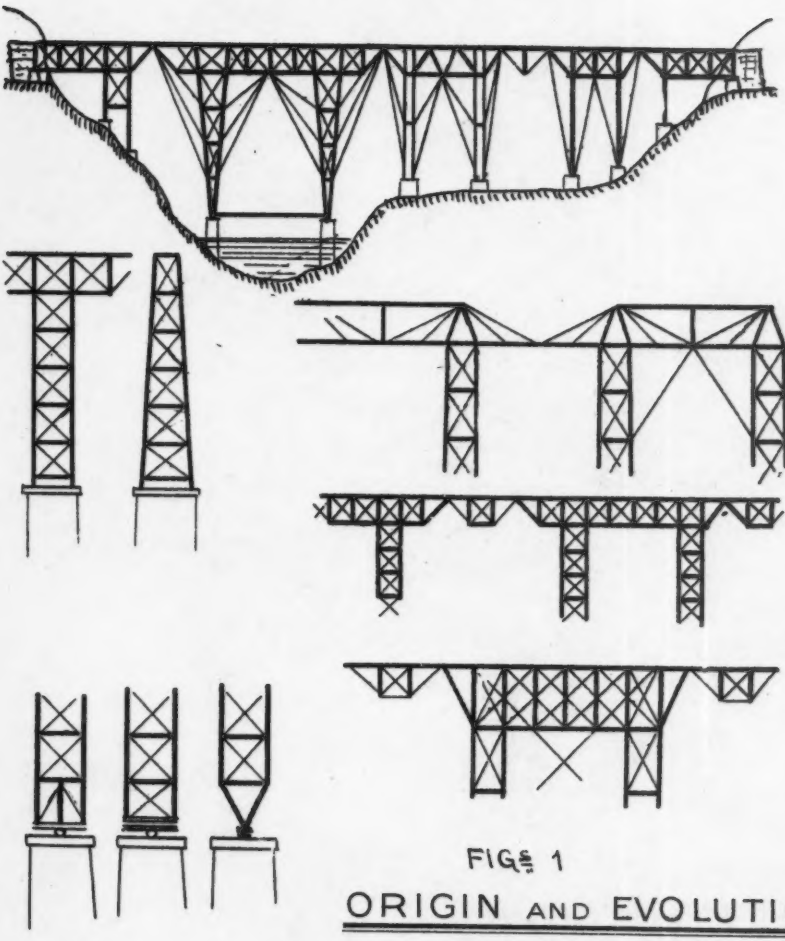

ELEVATION.

SKETCH OF VIADUCT
EAST RIVER
CROSSING BLACKW

PLATE LXXXI.
TRANS. AM. SOC. CIV. ENG'RS.
VOL. XXV. Nº 503.
GREINER. ON
HE ORIGIN OF THE R.R. VIADUCT.

F VIADUCT APPROACHES.
T RIVER BRIDGE.
NG BLACKWELL'S ISLAND.

C.BENDER - 1870



FIGS 1

# ORIGIN AND EVOLUTION OF THE AMERICAN RAILROAD VIADUCT

EDWARD W. SERRE

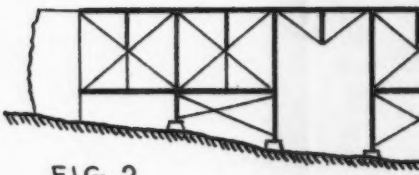
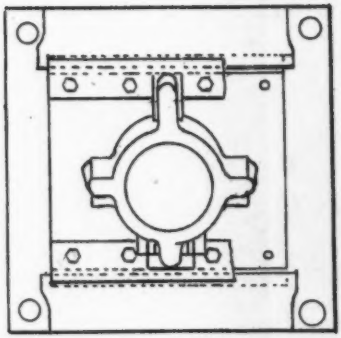


FIG. 2

FIG. 3

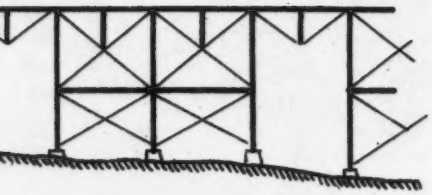


EVOLUTION

HE

OAD VIADUCT.

.SERRELL-1871



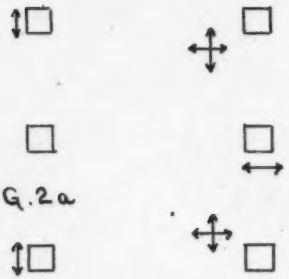
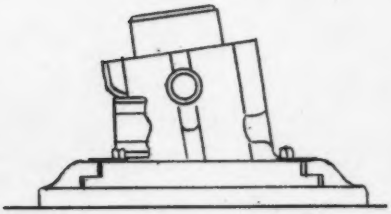


FIG. 2a

FIG. 2b



attribute to any one person the origin of what is called the American viaduct.

E. THACHER, M. Am. Soc. C. E.—During the past two years I have designed between 10 000 and 11 000 linear feet of iron or steel viaduct; all of it, with the exception of the Hill City approach to the Chattanooga bridge, was for railways, and manufactured and erected by the Shiffler Bridge Company of Pittsburgh. All of this work consisted of iron or steel plate girders spaced 9 or 10 feet between centers, supported by iron bents braced laterally and longitudinally in the form of towers, as has been the general practice for some years. Among the highest of these structures is Buffalo Trace on the Kentucky Midland Railroad, 153 feet; Neal's Branch on R. N. I. & B. R. R., 190 feet; and Marble Creek on the same road, 210 feet in height. This latter structure had some interesting features. The line passed along the edge of a narrow precipice, and the cross-sections were very irregular. In one bent one leg was 52 feet longer than the opposite one, the base and one intermediate point being strutted and anchored back to the rock. In another bent one leg was 26 feet longer than the opposite one. The length of spans in these structures ranges from 36 to 70 feet. Some years ago I made some estimates to determine the most economic span for different heights, and found, using the specifications of the Keystone Bridge Company of that date, and disregarding the cost of pedestal masonry, that for all iron structures the spans most economic of material are as follows:

For heights up to 55 feet, all spans 30 feet.

For heights from 55 to 91 feet, 30 feet towers and 40 feet intermediate.

For heights from 91 to 129 feet, 30 feet towers and 50 feet intermediate.

For heights from 129 to 200 feet, 30 feet towers and 60 feet intermediate.

Using steel girders and taking into account the cost of masonry, the economic length will be somewhat greater than as given above. In Marble Creek viaduct 70 feet spans were used at the highest point. The length of span is governed in many cases by the nature of the foundations and the convenience in erection. When it much exceeds 70 feet it becomes a difficult matter to construct a traveler that will handle the material economically, and unless the structure exceeds 250 feet in height I doubt if anything is gained by the use of spans longer than 70 feet. The statement of the author that the single leg type of structure is cheaper than any other is not borne out very well by the facts. I made an estimate some years ago on a design of that kind furnished, I believe, by C. Shaler Smith, and the cost, as nearly as I recollect, was about double what it would have been with braced bents. The Bullock Pen and other early viaducts on the L. and C. Short Line

Railroad had one defect probably not contemplated by the designer. The inspector who came around often to tighten up the rods with a 3-foot wrench was too ambitious, and succeeded in several instances in lifting the legs off of their pedestals.

The evolution of the viaduct during the past twenty years has been no less in general design than in detail, but as the author does not touch that part of the subject, I will not take it up.

T. C. CLARKE, M. Am. Soc. C. E.—My only claim is that I designed the viaduct illustrated in Plate LXXX, for the reasons given by the author of the paper. The design and the date of the drawing speak for themselves. Every viaduct built by Clarke, Reeves & Co., including the greatest of all—that at Kinzua—was built after this design, which is now being copied by European engineers. The plate is reproduced from a tracing of the original drawing, now in the Phœnix Bridge Company's office at Phœnixville.

A. P. BOLLER, M. Am. Soc. C. E.—Mr. Greiner's paper on the genesis of the modern railroad viaduct seems to cover all the main points of their origin and development, and leaves little more to be said on the subject. The paper is so suggestive of collateral history in the development of iron bridge building in America, that it may be well to put on record some unwritten chapters of that history made by men who were important factors in shaping the line of development in the early days of the art. Through purely accidental causes the three great nascent railway systems of those days, adopted three separate ideas of bridge building—the Baltimore and Ohio school, under the lead of Albert Fink and Wendall Bollman, developing the trussed suspension type, of which school Shaler Smith was a brilliant pupil; the Pennsylvania Railroad school, headed by Jacob H. Linville, under the inspiration of the early writings of Squire Whipple and his pupil John W. Murphy (now deceased), who had settled in Philadelphia to engage in the building of bridges (since known as the Murphy-Whipple bridge), first with A. & P. Roberts and afterwards with Stone, Quigley and Burton, noted wooden bridge builders of the day; and the New York Central school, under the lead of George E. Gray, which adopted the riveted lattice type through the influence, if I am not mistaken, of Howard Carroll (killed during the war), one of his assistants, a brilliant young Irish engineer who had been brought up under Sir John MacNeil, and was therefore thoroughly imbued with English ideas. Mr. Hilton was also a pupil of Mr. Gray and an associate of young Carroll, and was very active in Americanizing the riveted lattice truss, and fastened for all time that type as the standard of the New York road. Outside of this road and the tributaries which it influences, the Whipple type (often erroneously called the Pratt), excepting for small spans, has been universally adopted throughout the country as the most economical and constructively the simplest, even as foreshadowed by the retiring and

modest mathematical instrument maker, who, without precedent or example, evolved the scientific basis of bridge building in America. It may be interesting to note that Mr. Whipple's first essay, in which he showed a rational method of computing bridge strains, and the manner of using material as the facilities of the shops of the day made possible, was published in 1847. The type was set up by his own hands, the cuts made by him, and my impression is the presswork was his also. The edition was a very small one, very crudely printed and illustrated. For some cause or other the author suppressed most of the edition, but fortunately a few copies became distributed and opened the eyes of the early builders to the scientific principles of their art. Some years since, while collecting data with a view to writing a history upon iron bridge building in this country, I received several communications. A very interesting one from Mr. Whipple, the *Railroad Gazette*, published in 188—. I add in this place a communication from Mr. Linville and one from Mr. Gray, the respective sponsors for the character of the development on the Pennsylvania and New York Central railroads. They tell in their own way the story of their early efforts and the difficulties with which they had to contend. I find among my papers a characteristic letter of Mr. Whipple, which ought to be put on record for its historic references. It was written shortly before his death, and it is difficult to realize the clear, firm and legible handwriting of the original, as that of a man eighty years old.

ALBANY, January 10th, 1887.

A. P. BOLLER.

*Dear Sir:*

In answer to yours of the 7th, I can not do better than to quote from the advertisement of my publication of 1869.

"It may be proper on this occasion to explain the somewhat anomalous —perhaps I should say incongruous, form in which this book is presented. The original publication was a pioneer effort, prompted by a hope of being able to do something toward supplying an important desideratum. It is believed that no previous attempt had been successfully made to reduce truss-bridge construction to its simplest elements, and to determine by exact calculation the forces acting upon the various parts of such structures, and to deduce thence the proper sizes and proportions of such parts, upon known and reliable principles. This was the purpose and object of the author, which was tolerably satisfactory to himself, and met as favorable a reception as could have been expected. But perfect success in all respects could hardly be hoped for in a first endeavor of the kind, and observation and reflection early suggested additions and modifications, which it seemed might make the work more valuable and useful, insomuch that its dissemination, in its then condition, was not regarded as especially desirable. Consequently, of the edition first printed, which would have been exhausted long ago had the book been easily accessible, a considerable number of copies remain still in the hands of the author, while those which have been disposed of have mostly been parted with on direct application to him, and not through the medium of the book trade. Recently, however, circumstances and inclination favoring, the author has prepared and printed with his own

hands entirely (having turned printer and xylographer for the occasion), the present addition to the matter originally published,* whence it will be seen that the history of its production is as unusual as the character of the book itself."

1st. My work was entirely original, built up on elementary principles, without reference to, or knowledge of any previous work upon the subject.

2d. I first met John W. Murphy about the year 1850 or 1851. I learned that he thought well of my book and my bridges, whence I inferred, of course, that he was a man of discrimination and ability, and as he afterwards talked up iron bridges and Whipple bridges in Pennsylvania, he was of service to the cause and to me. Iron bridges "took" in Pennsylvania rather better than in New York, and Murphy, with others, formed a partnership for building iron bridges, and purchased my patent (covering the arch truss only), in the year 1859, or thereabouts, and built a few bridges, which they were pleased to designate as Murphy-Whipple bridges, to which I made no objections, though it has perhaps been the means of disseminating false impressions. "Murphy-Whipple bridges," properly considered, simply means bridges built by Murphy upon plans and principles originated by Whipple. My relations with Mr. Murphy were most friendly, and he conceded to me all my claims to originality in the bridge question.

3d. To the best of my recollection, the first iron bridge erected for the New York Central was over the Mohawk at Schenectady, in 1858 or 1859, or thereabouts, being designed by Howard Carroll, George E. Gray being Chief Engineer of the road. Mr. Carroll complained that he was restricted to some other plan than Whipple's, and the bridge was constructed with diagonal braces and vertical ties (*a la* Howe), as I recollect the case. When and by whom the plan was changed to a web system without vertical members, I am unable to say.

Howard Carroll was a man of fine presence, 6 feet in stature, and

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*Copy of a card attached to my model Exhibited at the Centennial exhibition.—S. W., Printer.

## THE ORIGINAL:

## Made in 1846, and exhibited in the

## AMERICAN INSTITUTE FAIR

## In 1847.

This is the first model constructed to represent the WHIPPLE TRAPEZOIDAL TRUSS BRIDGE, and is believed to illustrate the first intelligent attempt to introduce from actual calculation, correct proportions for the several parts in Bridge Trusses or Girders, according to the duty required of the parts respectively; and, to reduce to a PRACTICAL MINIMUM the material required in the construction of Bridges.

JULY 4th, 1876.

SQUIRE WHIPPLE,
ALBANY, N. Y.

every inch a gentleman. He served in the war for the Union—with a colonel's commission—was in several hard engagements, and lost his life in the service. Honor to his name.

This is about all I can say in answer to your queries. I would like, however, to call your attention to an advertisement of the Rider bridge, and its endorsement by some of our most prominent engineers (to be found in the *Railroad Journal* of the year 1848, pages 775 and 776), as showing how little attention the profession at that time had given to the elementary principles of bridge construction. It seems to have been mostly a mere matter of "cut and try," and if the thing stood, all right, and no questions asked as to whether the structure contained too much material here or too little there.

Very respectfully yours, etc.,

S. WHIPPLE.

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PHILADELPHIA, November 19th, 1886.

MY DEAR MR. BOLLER:

I send herewith a hurried statement, given below, of my most important work in iron bridge building. During my early connection with the Pennsylvania Railroad Company, the charge of maintenance of way and construction devolved on me, and much of my time was also employed in designing and constructing shops and stations. Bridge work for the entire line, from Philadelphia to Pittsburgh, was also mainly under my charge; in fact all the iron bridges were then designed by me and constructed in the Altoona shops. This subject was new to me, the demand urgent, and my force limited, consequently I was always overworked, and my health, naturally delicate, soon became permanently impaired.

When relieved from maintenance of way, I became engineer of bridges and buildings, when the designing of the bridges and buildings for the main line and dependencies was entrusted to me. In the Keystone Bridge Company the case was similar. The executive work was done by me and the designs were mainly made under my direction. There was no time to fully mature anything, no leisure for study or calm reflection. My energies were exhausted and health broken down by the incessant demand for estimates and plans; and in traveling involved in making proposals, visiting work in progress, and in settlement of questions growing out of work under construction. I gave about two hours' time to the draughtsman who prepared the design for the river span at Callowhill street, Philadelphia, and received the first premium from the city. The original design and estimate for the Steubenville Bridge was prepared in one or two days, a statement furnished showing the size and weight of the principal members, and a list of necessary tools made out, if the work was to be constructed in the Altoona shops.

I had a preference for spans constructed with inclined struts and ties, and besides numerous small trellis bridges, designed a 262-foot span for Port Perry, but the bridge was not then constructed, and later Mr. Wilson prepared the designs. I always feared, however, that trouble would arise from the wearing of the eyes and pins resulting from changes from tension to compression and *vice versa*, under moving loads. In Middletown Bridge provision was made to compensate for the wear.

Trusting I have not wearied you with details, interesting only to myself, and too many apologies for my failures, which, perchance, I might avoid if I could live my life over again,

I remain yours very truly,

J. H. LINVILLE.

Another letter from Mr. Linville reads as follows:

The subject of bridges was not embraced in the course of study at Union College. I pursued the regular classical course, and took many optional studies from the scientific course, including analytical geometry and the calculus. When I resumed the duties of Resident Engineer of the Middle Division, Pennsylvania Railroad, I was entirely ignorant of bridge construction and the requisite computations, but was soon directed to build, in the shops of the company, the third trusses for Duncannon Bridge, from existing patterns. This led me to inquire, and I found Haupt's book on bridges, but obtained little information therefrom. I increased the strength of the third truss mainly in the suspension rods near the ends, but the patterns precluded the possibility of securing enlarged counters. Next I built Bridge 13, near Tyrone, from new patterns, also Bridges 6 and 7, west of Spruce Creek, all arched Pratt trusses. I proposed wrought-iron upper chords, but Mr. Thomson objected. This was in 1857–59. In 1860, Mr. Thomson advertised for plans for the Delaware extension bridge over the Schuylkill River, Philadelphia. I submitted a design, all riveted lattice, also a design with wrought-iron hollow posts and with flat chord links, four abreast, distributed each side of the two suspension diagonals and between ribs on the cast bases of the posts. The trusses were double intersection and posts vertical. I had no books except Haupt's, when, by considerable hard study, I discovered the formula given in the "Keystone Album," page 29. Afterwards I secured a copy of Whipple's first book and a copy of "Bow on Bracing." I had seen a plan of a Whipple bridge erected near Troy, N. Y., and had a lithograph of a Fink bridge, 200 feet span, near Monacocy. The rest was evolved from my inner consciousness. My hollow post design was adopted by Mr. Thomson over the Phœnix and numerous other designs. The lower chords were forged by John A. Wright at Freedom, with wide, rough, flat heads, and trimmed into shape at the Altoona shops. This led to investigations and experiments by Piper and myself, when the upsetting of chord heads by pressure in moulds was invented in 1861. The patent was finally sustained over the Phœnix by the Supreme Court. The hollow post patent was also confirmed to Piper and myself, but just at the time of the expiration, we discovered that both parties had been anticipated by an English patent for rolling pipes in flanged sections.

I built the Schuylkill Bridge in 1861. The specifications given by Mr. Thomson limited the live load to 2 400 pounds per lineal foot, and required the diagonals to have screw adjustments, and the floor beams to be carried on the chords. This requirement applied to all bridges built while he was president. He would not consent to eye-bolts at both ends of suspension diagonals or to the use of suspended cross-girders, and you will find this limitation affecting all the bridges built during his time on the Pennsylvania Railroad. I constructed the bridge at Rockville and the Pequea bridge, near Leaman Place, at about the same time as the Schuylkill bridge, but with cast-iron posts; otherwise the plans are similar. In 1862, I was requested by Mr. T. A. Scott to submit a plan for a 320-foot span at Steubenville. I had, in the meantime, seen Humber's work on bridges. Mr. Thomson prescribed a live load of 2 500 pounds per foot. I urged a heavier load, and after his return from England he consented to allow 3 000 pounds per foot in this bridge and in all subsequently built for the Pennsylvania Railroad. I could not obtain the hollow posts for this bridge, and there was only a limited variety of shapes then rolled, consequently I was led to use cast-iron in the posts. Mr. Thomson was very partial to cast-iron and resisted innovations. This

is the first bridge I built with leaning end posts, although I was aware of the economy in that form. Enoch Lewis objected to inclined posts when proposed previously for the Rockville bridge. He did not like their appearance. In the Steubenville deck spans I employed auxiliary rolled beams to carry the floor beams, and this plan was adopted for bridges above Lewistown, Manayunk, Mount Union and Coatesville, the compression being taken by a cast-iron upper chord. In 1863 I advocated bridges entirely of wrought-iron in a circular issued by the Keystone Bridge Company. In 1865 I induced Mr. Thomson to adopt wrought-iron for the 262-foot span for the connecting railway bridge over the Schuylkill River, but he still adhered to cast-iron for small bridges. This was the final triumph for wrought-iron, although after this bridge was finished he ordered me to continue the counters to the ends for appearance, and to put on an arch. I succeeded, after considerable persuasion, in obtaining permission to attach the arches so that they could not support any weight. Then followed bridges at Easton, for the Lehigh and Susquehanna Railroad Company, and the Newport and Cincinnati bridge, of which I was chief engineer. We were making octagon hollow posts and upset chord links in 1865. The Newport and Cincinnati bridge had a span of 420 feet, to carry 4 500 pounds per foot, and a pivot span of 360 feet, afterwards abandoned when the Government required us to elevate the bridge from 70 feet (as designed and partly erected) to 100 feet above low water. This ruined the general design and necessitated patch-work expedients to save the work, then mainly constructed and partly erected.

After this followed the channel spans of the Benwood and Parkersburg bridge over the Ohio, and of the Dubuque and Keokuk bridge over the Mississippi. The Keokuk pivot span was 378 feet. I do not mention the multitude of short span bridges mainly designed by me for the Keystone Bridge Company. The next notable structure was the Schuylkill River span at Callowhill street, for which was awarded to me the first premium from the city. This bridge was ruined in appearance by the requirement of cast-iron arches (afterwards changed to galvanized iron) to match the design made by Mr. Kneass for the approaches. The Raritan Bay pivot span, 472 feet in length, was designed about this time. Then followed the channel span, 520 feet, for the Cincinnati Southern Railroad Company over the Ohio River at Cincinnati. I condemned Captain Eads' first design for the St. Louis bridge (which ended my connection therewith as consulting engineer), and suggested arches in depth one-fortieth of the span, with the material in tubular form, instead of his solid rib about 8 inches square.

Aside from my connection with elevated railway work and the Kinzua viaduct, I do not recall anything further worthy of mention. I always favored heavier bridges and numerous changes in details, which I was prevented from making, owing to the close competition and the requirements of manufacture. Our "Keystone" practical men were averse to change, but gradually fell into the use of wrought-iron box posts and chords, and later, latticed posts. The subject became tiresome and monotonous to me as I became worn in health and spirit by overwork, and I do not believe anything short of a phenomenal structure could again arouse my interest in bridge work. If you will refer to Clarke's book on the Quincy bridge and probably Merrill's book and many others, you will find strains allowed in counters at the extreme ends of spans. I do not claim this as a brilliant mathematical achievement, but considering that it was original, and developed by laying awake one night and without any aid from books, and at a time when I was in a deplor-

able state of ignorance, I always felt somewhat proud of the result. Three years ago I made a bonfire of numerous letter-books and bridge plans, as they were in my way in the country. My Keystone letter-books were shipped to the Keystone Bridge Company, Pittsburgh, and are in the attic. A fire destroyed my house and library some years ago, and I can only give you this hurried sketch from memory. I care nothing for fame, and only fear that your generosity and friendly feeling may lead you to give me greater credit and praise than I merit, as I utterly despise all that I ever constructed, and with the present light cannot comprehend why I did not accomplish something better. I presume every tyro from the schools now wonders why mistakes, now so apparent, were made, but no one can realize and understand these things who has not groped in untrodden paths as did the early builders of American bridges.

MAY 23d, 1887.

Memoranda relating to the introduction of wrought-iron bridges (lattice) on the New York Central Railroad, made by the late Chief Engineer, George E. Gray:

The engineer of this period cannot fully realize the embarrassment his predecessors labored under to keep pace with the march of improvement of the country by the introduction of railroads as a means of transportation. In no particular case was this more evident than in the designing and building of bridges and other structures of like character on the New York Central Railroad, prior to 1853, the year the several companies between Albany, Troy, Buffalo, Niagara Falls, etc., were consolidated. In that year the writer was appointed Chief Engineer of the consolidated company, the New York Central. His powers and duties were limited to the designing and constructing new works, and when completed, turning the new work over to the local superintendent's care and maintenance.

This condition of responsibility continued until 1858. On May 11th, 1858, a serious accident occurred at the Saquoit Creek bridge, about four miles west of the City of Utica, resulting in great loss of life. This accident brought to the attention of the directors of the company the subject of where the responsibility rested for the care and maintenance of the bridges on the line of the road. Investigation brought out the fact that there was no organized system of inspection of the bridges. The Chief Engineer was then requested to suggest a method of inspection, which was approved by the Board of Directors by resolutions requiring the Chief Engineer to make a careful inspection and test once in six months, and report to the directors such recommendations as seemed proper. In addition, the local superintendents and roadmasters were to make independent inspections every three months on their several divisions and report to the Chief Engineer. Under this system the first inspection brought to light a most lamentable state of the condition of the bridges. The several companies forming the consolidated company had constructed their roads on very economical methods. The bridges were of every conceivable design, and when the designer had knowledge and experience to proportion the parts properly, the load provided for contemplated engines not exceeding 20 to 25 tons, the latter considered heavy. Then, bridges had been neglected, many vital members were badly decayed, important bolts and tie rods were rusted and not properly adjusted, and as a whole, were unequal to carry safely the fast increasing traffic. This condition as found, the perishable character of the material

(wood), and the frequent renewals (unless covered in, increasing risk from fire, etc.), led up to the question, Is there a more durable material for bridges? Can we substitute iron and stone within a reasonable cost? Iron bridges were the order of the day in Europe, but their reputed cost disheartened our directors. The income would not warrant the outlay. Again, the lack of proper information prevented a full understanding of the subject. At that period there was not an all wrought-iron bridge on any railroad within the United States (to the knowledge of the writer), except an example or two of short-span plate girders. My old friend and mentor, Squire Whipple, of Albany, N. Y., had designed and constructed a few combined cast and wrought iron bridges. The directors of the New York Central Company had great distrust of iron for bridges, but in particular of cast-iron, and they would not entertain its use. This led to the study of wrought-iron suited to the purpose of the New York Central. The only hope was to so reduce cost as to come within the means of the company, and this could be done only by reducing quantity of material.

The European engineer had abundance of capital and cheap labor; the American engineer had the cost of the article, to which must be added transportation, custom duties, and the high price of labor, both skilled and common; and another difficulty, a want of information and experience in iron bridge building. There were no civil engineering societies to bring civil engineers together where they could exchange ideas and tell their experiences. The literature on this subject was limited. The writer sought every known publication at home and in Europe, and when all was sifted it was not satisfactory beyond demonstrating that wrought-iron, as used by European engineers, was beyond the financial power of the New York Central Company. However, the query came to the writer's mind, why not cut out what seems unnecessary material in European plans?

Working from this idea, and from data obtained, plans and calculations were prepared for a few short span lattice bridges. The best forms for compression and tension members and for the joining of members were designed. The formulas for calculating compression strains, without bending, etc., were wanting or unsatisfactory. Fairbairn and others gave compression formulas, but nothing satisfactory for deflection. A halt was made until a testing machine could be made, and then the several sections designed were tested, and from these tests formulas were obtained from which all the designs for lattice bridges on the New York Central were developed. When designs had been prepared it was discovered that very few of the forms or sections desired could be had, except at extra cost for the rolls; rolling mills did not wish to undertake such small invoices, and only limited sizes of flat bar and angle and T iron could be had from merchant stock. Many makeshifts had to be resorted to in filling a bill of iron for any bridge, and many changes involving new calculations became necessary. The engineer who may now be called upon from curiosity or investigation to examine those early examples must in justice bear in mind that nearly all the sections or forms he may see are not the original choice of the designer, but forms forced upon him from the want of better. The increasing traffic admonished the engineer to meet the demands for heavier rolling stock, etc. Therefore the new designs prepared contemplated 1½ tons per lineal foot of single track. The designing and construction proceeded cautiously, but steadily. Small spans were first constructed (and these attracted the attention of railroad officials), notably the bridge over the Mohawk River at Schenectedy and the Hamburg Street Canal in Buffalo. These bridges met our expec-

tations; superintendents and roadmasters approved them, and asked for more of the same sort. The Board of Directors began to feel confidence in wrought-iron, and indorsed by resolution the recommendation of the Chief Engineer to replace all wooden bridges by iron as fast as they required renewal. About this time rolling mill managers began to see the growing importance of iron in bridge building.

Among the first long span bridges erected was a double track bridge, of 125 feet span, over the Tonawanda Creek at Batavia, N. Y. This bridge was constructed and brought into use in 1860, the plans having been ready a year before. This structure has but two trusses, the floor beams being of depth to carry the weight of both tracks. The location is near the home of the late Dean Richmond, Esq., the then Vice-President of the New York Central Company. Mr. Richmond watched the progress of this bridge with deep interest. When completed and tested by the heaviest engines then in use, filling the two tracks the entire length and speeding the engines, all of which it bore to our entire satisfaction—Mr. Richmond being present, he turned to the writer and said: "Well, Mr. Chief Engineer, there is a monument for you that will last long after you and I have gone to dust. That is the kind of bridge I am in favor of; no more wooden bridges for this company."

After the completion of the Batavia bridge others followed rapidly, confidence seemingly fully established, the main conflict being the great cost. The next in order was a double track bridge on the Erie Canal near Newark, another on the Erie Canal at Rome, and another on the Erie Canal at Schenectady. The first iron bridge was erected in 1859 and 1860. During the fiscal year ending September 30th, 1862, there were constructed 697 linear feet, making a total to that date of 4 670½ linear feet equivalent, single track. September 30th, 1863, 499 feet were added, making a total of 5 169½ feet; September 30th, 1864, only 130.$^{6}/_{12}$ linear feet were added. During the year 1865, the total linear feet of equivalent single track on the whole line was 5 677.$^{8}/_{12}$ feet. In addition to the long spans constructed, a large number of small spans were built, forming in the aggregate a formidable bill of expenses chargeable to bridge renewals.

The duties of his position as Chief Engineer of the New York Central Railroad (always arduous) required additional assistance other than the ordinary routine. Mr. Howard Carrol, a young Irish civil engineer, who had served under Major McNeil in Ireland, was employed. Mr. Carrol had some experience in the erection of small span plate girders. His experience, fitness by education, and his inclinations made him a valuable assistant. From the data already obtained and the writer's constant personal supervision, the first design and the calculation of strains and tests for the lattice bridges were brought forth, and the bridges constructed as now seen on the New York Central Railroad. Mr. Carrol continued in this special duty until his resignation. Mr. Carrol's love for his adopted country prompted him to assist in raising a regiment of New York State volunteers for service in the war of the rebellion. With this regiment he went to the front as the Lieutenant-Colonel. It was in this serving, while gallantly leading his brigade at the battle of Antietam, that he received wounds from which he died a few days after in Washington, D. C. Thus died a noble man and a ripe scholar, who, had he lived, would have made more than an ordinary mark in the history of iron bridge building.

Mr. Chas. Hilton was another assistant serving with Mr. Carrol, and succeeded the latter after his resignation. Mr. Hilton succeeded the writer when he resigned his position of Chief Engineer, to take that

of Constructing Engineer to the Central Pacific Railroad of California. He continued the designing and construction of iron bridges on the New York Central until his retirement, and afterward devoted himself to constructing and building iron bridges, making some modifications in minor details.

J. E. GREINER, M. Am. Soc. C. E.—The author regrets that the original intention of entering into the details of viaduct construction was not carried out, because there is sufficient evidence in the foregoing discussion to indicate that such a diversion would have been pretty thoroughly ventilated.

In answer to Mr. Moore, the author did not intend to convey the impression that the single leg type of structure is cheaper than any other in all cases, but can see no reason why Mr. Bouscaren's opinion that, "circumstances permitting its use, it is superior to others," should not be correct. The fact that a particular case figured by Mr. Moore required an excessive amount of material proves nothing to the contrary.

Concerning the proper lay-out of spans, the engine loads, material used and cost of the same erected, enter into consideration, and the economical lengths for light engines will not always be economical for heavier loads. For instance, a single track viaduct proportioned for the 107.5 ton Baltimore and Ohio consolidated engines will weigh very nearly, for 30 x 30 feet spans, 440 pounds per linear foot, and 340 pounds per vertical foot at 30 feet intervals; the height being taken under the girders. For 30 and 60 feet spans the weight would be 650 pounds per linear foot, and 400 pounds per vertical foot of bents. The height of the legs which will give the same weight of iron for each case can be approximately determined from the formula—

$$2.4\,h\,s + 60\,h = 210\,s$$

where $s$ = the total length of structure, $h$ = the average vertical height of legs to give the same weight of structure.

Thus, when

| | | | |
|---|---|---|---|
| $s = 360$ feet. | $h = 81.7$ feet. | $s = 720$ feet. | $h = 84.6$ feet. |
| $s = 540$ " | $h = 83.6$ " | $s = 900$ " | $h = 85.1$ " |

If it is assumed that there will be about 7 cubic yards of masonry to each bent, that masonry costs \$12 per cubic yard, and iron 4¼ cents per pound erected, then the cost of the two cases will be the same when $102\,h\,s + 2.5\,h = 8\,s$ gives for

| | |
|---|---|
| 180 feet spans. | $h = 69.00$ feet. |
| 360 " " | $h = 73.44$ " |
| 900 " " | $h = 76.4$ " |

From the above it appears that the length of structure, as well as the height, will influence the lay-out.

There are many interesting points in viaduct construction which might be discussed, but this is not the time.

Mr. Moore seems disposed to criticise the author's limitation of the term viaduct to a structure of metal or wood supported by braced

towers. Of course such a limitation would exclude the stone viaduct, still there would be no objection to the classification of such bridges as "stone arches." The etymological meaning is too general and is not the one usually accepted. In this sense "a viaduct is a structure carrying a road." Then, according to this, the East River Suspension and the Niagara Cantilever bridges, as well as the Kinzua, are viaducts. No one, however, refers to the suspension or cantilever bridges as viaducts, and this clearly proves that the accepted meaning is limited to certain kinds of structures which cross ravines where there is little or no water. The definition given by the author is, perhaps, too narrow, and was advanced merely to bring out the views of others.

The collateral history on the development of iron bridge building in America, furnished by Mr. Boller, is by far more interesting than the author's attempt. In reading of these early efforts made to correctly design bridges, one necessarily feels a veneration for those great pioneer bridge engineers. Perhaps, as Mr. Linville says in his letter, "some tyro fresh from school wonders why it was possible to make mistakes now so apparent," but the same tyro invariably outgrows his wonderment. Every engineer worthy the name fully respects such men as Whipple and Linville.

In conclusion there is appended hereto a letter from Mr. Bouscaren, relative to the designs of the early viaducts on the Louisville and Nashville road, which explains itself :

DEAR SIR :

Referring to your remarks on the viaducts of the Cincinnati Southern Railway, I desire to state that the idea of substituting alternate 60 and 30 feet spans in place of all 30 feet spans, was first suggested to me by Mr. C. L. Strobel, who was at that time (1878) my assistant on the Cincinnati Southern Railway. He should receive due credit for the idea.

The Horse Run Viaduct mentioned in your paper was designed and built by the Keystone Bridge Co., under the condition to preserve the general feature as to longitudinal bracing, shown in your diagram.

Yours very truly,

G. BOUSCAREN.

CINCINNATI, July 16th, 1891.